Proceedings of the Department of Defense (DoD) Symposium

"DoD Entomology: Global, Diverse, and Improving Public Health"

Annual Meeting of the Entomological Society of America

14 December 2010

Town and Country Conference Center, San Diego, CA

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Preface

From the Director:

Since 2001, the Armed Forces Pest Management Board (AFPMB) has organized a symposium on some aspect of military entomology at the annual meeting of the Entomological Society of America. The 2010 meeting was held at the Town and Country Conference Center, San Diego, California, and our symposium was held on Tuesday, 14 December.

The theme of the 2010 symposium was "DoD Entomology: Global, Diverse, and Improving Public Health," with the intent of showing the diversity of non-entomology work performed by military entomologists, the worldwide impact of military entomology, and the positive impact military entomology has on improving public health in developing countries. The adaptability of military entomologists and the ability to lead and function in occupational areas not even closely related to entomology is one of many strengths found in the military entomology corps.

Lt Col Mark Breidenbaugh began the symposium with an unscheduled presentation on the oil spill in the Gulf of Mexico during the summer of 2010. This event occurred after deadlines for presentation submissions, but we were able to work this important talk into the symposium by minimizing the moderator and director's comments. Lt Col Breidenbaugh explained how entomological spray assets were used to apply oil-degrading treatments to contaminated areas in the Gulf of Mexico and thereby reduce the effects of the oil spill.

LTC Sonya Schleich discussed entomologists working outside the field of entomology and the types of work they did. Some worked with non-vector disease programs, commanded laboratories that processed human samples, worked issues related to water quality, procured medical equipment, trained foreign public health personnel, or commanded an overseas medical research laboratory.

COL Scott Gordon and LCDR Peter Obenauer discussed how US military medical entomologists built new partnerships in Africa to reduce the impact of vector-borne disease on that continent.

MAJ Kendra Lawrence, LT Ephraim Ragasa, Maj Stephen Wolf, Dr. Terry Klein, and Dr. Amy Morrison presented a series of papers discussing the work and impact of DoD programs and projects in the former USSR, Afghanistan, the Philippines, the Republic of Korea, and Peru. Their work, like that of COL Gordon and LCDR Obenauer, attempted to defeat disease and bring stability to large areas of the world.

To close the session, LCDR Jeffrey Stancil told of his experience on the USS Comfort and its response to the devastating earthquake in Haiti in early 2010. LCDR Stancil's presentation is perfectly in keeping with the theme of this symposium. It's global (Haiti), diverse (working a non-entomology job), and served to improve the immediate medical and, later, public health of a people in crisis.

My sincerest thanks to LTC William Sames, Chief of the AFPMB's Operations Division, for organizing and moderating this symposium, and for compiling, editing, and coordinating the completion of these proceedings. I also thank Lt Col David Bowles and Dr. Richard Robbins for their reviewing and editing of these proceedings.

You can learn more about the AFPMB by visiting our website, www.afpmb.org, where a PDF copy of these proceedings will be available for downloading from our Literature Retrieval System.

On behalf of the authors and staff at the AFPMB, I hope you enjoy reading this compilation, and I would appreciate any feedback you might have.

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Disclaimer:

The opinions and assertions advanced herein are those of the authors and are not to be construed as official or reflecting the views of the US Departments of the Army, Navy, Air Force, or Defense. All studies involving human subjects were conducted using approved protocols. All experiments were conducted in compliance with the Animal Welfare Act.

List of DoD Symposia and Receptions at Annual Meetings of the Entomological Society of America, 2001-2010

2001 (9 Dec), "Military Medical Entomology, an Odyssey of Experience," San Diego, CA; moderator: LTC Nelson R. Powers.

2002 (19 Nov), "Careers in Military Entomology: A Global Experience," Fort Lauderdale, FL; moderator: LTC Raymond F. Dunton and 1LT Jessica L. Finkelstein. Military reception on 18 November.

2003 (26 Oct), "Careers in Military Entomology: A Global Experience," Cincinnati, OH; moderator: LCDR Michael D. Zyzak. Military reception on 27 October.

2004 (17 Nov), "Symposium: Medical Entomology Research in the US Military," Salt Lake City, UT; moderators: Maj Sharon L. Spradling and LCDR Michael D. Zyzak.

2005 (15 Dec), "Symposium: Medical Entomology Research in the US Military," Fort Lauderdale, FL; moderator: LCDR Michael D. Zyzak and MAJ Lisa L. O'Brien. Military reception on 16 December.

2006 (13 Dec), "Symposium: Department of Defense Entomology: To Serve and Protect," Indianapolis, IN; moderator: MAJ Lisa L. O'Brien and LTC Richard N. Johnson. Military reception on 11 December.

2007 (9 Dec), "Entomology in the DoD: Accomplishments and the Future," San Diego, CA; moderator: LTC Jamie A. Blow. Military reception on 10 December.

2008 (16 Nov), "Evolution of Military Medical Entomology," Reno, NV; moderator: LTC Jamie A. Blow. Military reception on 17 November.

2009 (14 Dec), "DoD Entomology: Unique Opportunities and Challenges," Indianapolis, IN; moderator: LTC Jamie A. Blow. Military reception on 15 December.

2010 (14 Dec), "DoD Entomology: Global, Diverse, and Improving Public Health," San Diego, CA; moderator: LTC William J. Sames. Military reception on 14 December.

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Deepwater Horizon: Entomologists and Oil Spills

Lt Col Mark Breidenbaugh and Maj Karl Haagsma
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Abstract. In the summer 2010, the Deepwater Horizon drilling rig exploded in the Gulf of Mexico, killing 11 platform workers and creating the largest oil spill disaster in the United States. The response to contain and reduce the damage of the oil spill involved the aerial spray capabilities of the US Air Force. Employing this capability, the Air Force applied oil dispersants to mitigate the oil spill consequences.

Presentation. The Deepwater Horizon drilling rig exploded on 20 April 2010, killing 11 platform workers. The wellhead was 4,000 feet under water and flowed for 3 months, ultimately spilling approximately 185 million gallons of oil into the Gulf of Mexico. This event created an oil spill disaster that was different than scenarios typically exercised by disaster response systems. Since oil rigs have so many fail-safe protections, disaster exercise scenarios focus on oil released from collisions of vessels, such as the wreck of the Exxon Valdez in Alaska that led to 11 million gallons of spilled oil.

The public often queries Air Force entomologists as to their mission in a military Service that, to the uninformed, does little other than fly airplanes. The general public has little knowledge of the complications of aircraft disinsection, vector-borne disease exposure to forward operating Air Force personnel, or the potential for transporting invasive species. Few know about the Air Force aerial spray capabilities, and fewer know that this capability can be used to mitigate oil spills. This paper discusses how the Air Force aerial spray capability was used to mitigate the Deepwater Horizon disaster.

Entomologists have specialized training in insect biology and pest control. Those entomologists involved in vector control, and who consequently understand the principles of insecticide applications, including the importance of droplet size, swath widths, and pesticide drift, will find that these skill sets are directly applicable to the aerial application of oil dispersants.

The DoD charges the Secretary of the Air Force to maintain a large-area, fixed-wing aerial pesticide application capability to control disease vectors, pest organisms and vegetation, as well as to treat oil spills in combat areas, on DoD installations, or in response to declared emergencies. To carry out these missions, a Modular Aerial Spray System (MASS) was developed for use with the C-130H aircraft. The MASS can be rolled on or off the C-130 airframe in approximately 30 minutes and has a maximum 2,000-gallon capacity for liquid materials. While the Air Force uses this equipment primarily for the application of ULV mosquito adulticides and liquid larvicides, the ability to apply many different liquids led to a collaboration with the U.S. Coast Guard as early as 1993, to evaluate the potential of using the MASS to deliver oil dispersants. These early tests of swath width and droplet size were conceptualized by Air Force entomologists, such as Terry Berry, John Putnam, Doug Burkett, and Brian Spears. The Oil Pollution Act of 1990 created contingency plans and the Oil Spill Liability Trust Fund, and the Air Force Application of Dispersants plan was included in the emergency response plans and a formal memorandum of agreement was created with the Coast Guard. Since 1993, this capability was exercised (practiced) several times on the east and west coasts of the US, in the Gulf of Mexico, and in Canada and England. Even though there were many alerts for activation of this capability following oil spills, the defense support of civil authorities' rules state that all civilian assets must be utilized prior to activating military ones. Thus, the Air Force capability had not been previously used in an actual response.

For Deepwater Horizon, civilian assets were in place and functioning within 24 hrs of the crisis. The Air Force's 910 Airlift Wing was alerted for potential use, but contacts at the Incident Command Center (ICC) indicated that mobilization was unlikely as it was believed that civilian assets would be able to handle the crisis. Two things changed that assessment. First, it appeared more and more likely that there would be no quick resolution to the leak and the ever-enlarging slicks, and second, the older civilian DC-3 aircraft were frequently being grounded for repairs. Eventually, the Air Force aerial spray capability was requested and, coincidentally, a spray-capable C-130 was in Lake Charles, Louisiana, demonstrating mosquito control capabilities. This crew and aircraft were able to immediately respond, and a second aircraft was sent to the area from Ohio. The first release of dispersant was completed on 1 May 2010, eleven days following the explosion. This was a career highlight for the first author, who was aboard the aircraft during this historic mission.

Oil is far easier to collect when it floats on open water rather than when it is washed ashore. In general, there is a three-pronged effort to prevent spilled oil from reaching the shore. The response crews for the Deepwater Horizon spill used a combination of skimming, burning, and the application of dispersants to recover oil. Skimming is certainly the most useful and desirable method because it recovers a reusable or marketable product. Burning removes oil from the water, and dispersants have a detergent-like effect, breaking up the oil into small drops which move below the water's surface and are broken down by natural processes. Skimming takes place close to the source, burning farther out, and finally the fast-moving aircraft apply dispersants over oil slicks that have escaped the previous two methods and represent geographically separated targets.

The Air Force was tasked to provide two C-130 aircraft and an additional spare aircraft in case of maintenance problems. Operations were based at the Stennis Airport in Bay Saint Louis, Mississippi. Two commercial aerial-spray aircraft shared the same facility.

Dispersant was initially delivered to the facility in totes and drums but later tanker trucks allowed direct loading of the MASS from the trucks. Aerial Spray Maintenance personnel were able to develop a "pit-stop crew" reloading capability using the tanker trucks and fire hydrant hoses. While keeping the engines running on the C-130, the quickest reload time was under 6 minutes and the aircraft was back in the air in 10 minutes. Using this quick reload capability, the Air Force aircraft completed 2 or 3 sorties compared to the one sortie flown by the commercial aircraft which had larger tank capacities but could not reload using the tank trucks. The Air Force mission statistics are given in Figure 1.

Because of well-established procedures and training, Air Force entomologists already knew which nozzles and flow rates to use, so after the daily sorties had become routine, the first author traveled to the ICC in Houma, Louisiana, where he served as the liaison officer and scientific advisor between the Dispersant

Operations Group and the Unified Command. Other Unit entomologists would follow, but only one entomologist worked in the ICC at a time.

- **Total gallons (g): 149,000**
- **Total acres: 30,000**
  - **Application rate: 5 g/acre**
  - **Dispersion rate: 1 g to 20 g of oil**
- **Total flying hours: 151**
- **Total sorties: 93**
- **Time in place: 30 April - 4 June 2011**

Figure 1. Mission statistics for Air Force aerial spray oil dispersant operations in response to the Deepwater Horizon oil spill.

Besides coordinating action between dispersant operations, entomologists developed procedures with the Coast Guard for the application of special monitoring of applied response technologies (SMART). The Coast Guard SMART teams measured efficacy of the applied dispersant. Later, the National Oceanic and Atmospheric Agency (NOAA) used fluorometric techniques to make the final assessment of dispersant application efficacy. Using SMART teams was an incident response plan requirement, but the massive nature of the oil spill made it difficult for SMART team boats, which move relatively slowly in comparison to aircraft, to catch up with the applications. By collaborating with the boat captains and the aircraft commanders, the entomologist assigned to the ICC was able to coordinate and help implement this required function, and the response functioned as shown in Figure 2. Spotter aircraft located oil slicks for which aerial treatment was appropriate, and the slick coordinates were sent to the SMART team for action. The SMART team made pre-application measurements and the application aircraft was instructed on how to spray the slick. The spotter aircraft directed left and right movements to keep the spray aircraft over the slick since the spray aircraft could not distinguish the slick from the non-slick areas at 100 ft altitude.

After the dispersal agent was sprayed, the SMART boat returned to the slick and measured the amount of oil dispersion. If it was not effective, a reapplication was ordered, although repeat applications were rarely needed.

By operational day 17, dispersants were being scrutinized by various groups, even though the dispersants were pre-approved for use as part of the incident response plan. However, there have always been detractors to the use of dispersants, and the scope of the operation, coupled with the apparent longevity of the incident, gave ample time to revive discussions on the pros and cons of using dispersants.

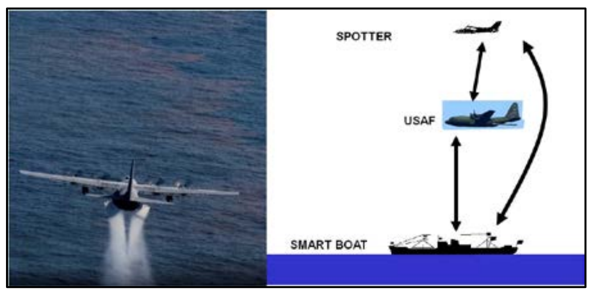


Figure 2. The interaction between the spotter aircraft, the application aircraft, and the SMART boat required significant coordination, and the successful interaction of these participants was due in part to the number of times these events had previously been exercised during training operations.

For example, when three workers on an oil rig platform became ill, they stated that they were in the vicinity of an aerial application. A review of the dispersant operations was ordered and dispersant applications were terminated pending the results of the review. Scientists from NOAA and regional agencies served as arbitrators to this claim and determined whether the workers were in contact with the drifting dispersants. If the workers had no contact with the dispersant, then they were ill from another factor.

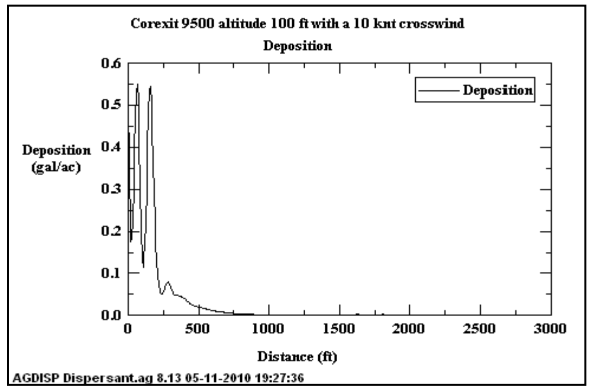
Spray aircraft GPS data showed the tracks of the aircraft were at least 3 miles from the rig with the sickened workers. The question of the moment was: "How far can these materials drift?"

By using the public domain computer model AgDisp (managed by the US Forest Service), the first author was able to show that even under a worst-case scenario, of a direct crosswind instead of into the wind (headwind), and a much higher release height, only the smallest drops, which make up 0.4 percent of the volume, ever travel beyond 1 mile of the release point (Figure 3). In this example under worst conditions, the closest applications were falling at least 2 miles short of the platform. In an ideal application, the aircraft approaches oil slicks by flying directly into the wind and the spray falls straight down behind the aircraft. This maintains the desired swath width and does not allow the spray to be blown off course by a crosswind. The data generated from the AgDisp model satisfied the arbitrators and the Federal On-Scene Coordinator (FOSC), Coast Guard Rear Admiral Mary Landry, and consequently aerial dispersant operations recommenced the following day.

Concern regarding the application of dispersants continued throughout the operation. The aerial application of dispersants became more and more restricted, and eventually the FOSC had to personally approve every application, which greatly slowed the response effort.

For years, the incident response plan had been exercised, and it included the pre-approved application of the dispersant (Corexit 9500®). These same materials are preapproved for use on the West Coast. The incident response plan must be modified if other dispersant compounds or alternative methods are desired for future responses.

As the response effort developed, commercial spray aircraft became available and relieved the Air Force of their stopgap function. The last Air Force application of oil dispersants occurred on 31 May 2010 and the Coast Guard subsequently released the Aerial Spray Unit, which returned to Youngstown, Ohio, on 4 June 2010.



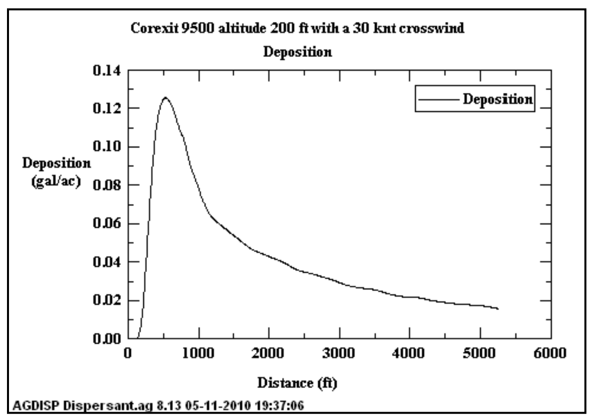


Figure 3. AgDisp model predictions. (A) A potential normal deviation from the application parameters of a 10-knot direct crosswind. (B) a worst-case scenario, aircraft is at 200 ft and spraying with a 30-knot crosswind.

For the Aerial Spray Unit, a significant and encouraging result was how closely the actual mission approximated how we had trained and exercised. For any military group, training "for how we fight" is the ultimate goal, and during the dispersant operations for the Air Force Aerial Spray Flight, there was very little difference between an exercise and the real thing.

Working Outside the Box: DoD Entomologists Do More Than Just Entomology

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Abstract. Today's Department of Defense Entomologist serves in a variety of positions outside those of conventional research or training and education. Military operations, humanitarian aid, and natural disasters have provided unique opportunities for our Corps. It is those opportunities we will explore through the presentation of several vignettes. Experiences range from serving as the Force Health Protection Officer for the Multinational Corps, Operation Iraqi Freedom, to identifying technology gaps as part of a research and development Field Assistance in Science and Technology Team. This collection of vignettes will provide a unique opportunity to explore the multifaceted experiences of the Military Entomologist.

Presentation. Today's Department of Defense (DoD) entomologist serves in a variety of leadership and technical positions outside the traditional entomological roles of research and pest management training, education, consultation, and supervision. Military operations, humanitarian aid, and natural disasters provide many opportunities for entomologists to broaden their skill base. The following short synopsis describes how seven (7) DoD entomologists served in non-traditional entomological roles.

Field Assistance in Science and Technology Team Member. An Army entomologist (Lieutenant Colonel (LTC)) served as the Medical Operations Officer to the United States (US) Army Research, Development, and Engineering Command (RDECOM), Field Assistance in Science and Technology (FAST) team in Iraq, 2009/2010. This Officer represented the United States Army Medical Research and Materiel Command (MRMC) and, as part of the team, identified technology gaps for medical and non-medical issues and liaised with Army laboratories and centers in the development of new technologies and/or material solutions for soldiers in the field. The other team members were assigned to one of the many RDECOM laboratories or centers within the United States Army Materiel Command (AMC). Research, development, and improvements for both medical and non-medical items are a primary mission for the Army's MRMC and RDECOM.

The team documented over 50 capability gaps and assisted in the development of new technologies to bridge identified gaps and/or assisted in making commercially available products available to soldiers in the Iraqi Theater.

Examples of some items that were commercially unavailable but required for entomological surveillance include: a flexible, lightweight solar panel capable of supplying at least seven days of continuous power to operate the standard CDC light trap and collapsible enough to fit into a jacket or pant pocket; and a lightweight, compact and stable, telescoping tripod for hanging a light trap or ambient air monitor when no other means are available (no trees or manmade structure). In addition to soldier feedback on existing products, non-entomological information was gathered for researching and implementing modifications and improvements to items such as the Interceptor Outer Tactical Vest (IOTV), the Army Combat Uniform, the Mine-Resistant

Ambush-Protected (MRAP) ambulance, quick release litter brackets, and ergonomically configured platforms used by soldiers while standing in vehicles.

The MRMC provides soldier support through medical research, development, and acquisition. The ability to provide this support is executed through commands such as: the US Army Medical Materiel Agency (USAMMA); the US Army Medical Materiel Development Activity (USAMMDA); the US Army Medical Research Acquisition Activity (USAMRAA); the Walter Reed Army Institute of Research (WRAIR); the US Army Research Institute of Environmental Medicine (USARIEM); the US Army Medical Research Institute of Infectious Diseases (USAMRIID); the US Army Medical Research Institute of Chemical Defense (USAMRICD); the US Army Institute of Surgical Research (USAISR); and the US Army Aeromedical Research Laboratory (USAARL).

The Army Materiel Command's (AMC), RDECOM centers and labs provide primarily non-medical support to everything a soldier uses, as summarized by the following excerpt from the AMC homepage: " If a soldier shoots it, drives it, flies it, wears it, eats it or communicates with it, AMC provides it."[1] The labs and centers subordinate to AMC's RDECOM are: Armament, Research, Development and Engineering Center (ARDEC); Tank Automotive Research, Development & Engineering Center (TARDEC); Aviation and Missile Research, Development and Engineering Center (AMRDEC); Communications-Electronic Research, Development and Engineering Center (CERDEC); Natick Soldier Research, Development and Engineering Center (NSRDEC); Edgewood Chemical and Biological Center (ECBC); and lastly, the Army Research Laboratory (ARL).

Commanding Officer, Navy Drug Screening Laboratory. From 2007 to 2010, a Navy entomologist (Commander (CDR)) commanded the Navy Drug Screening Lab, Jacksonville, Florida. The lab provides forensic chemical analysis of urine specimens for controlled substances and illegal drugs as deterrence to decreased Warfighter readiness. In 1980, the DoD conducted a survey in which 34% of Navy members surveyed admitted to using drugs in the past 30 days. The rate of drug abuse in 1980 led to the Navy's expanded forensic urinalysis program established in 1981 as the most cost-effective and scientifically defensible means of detecting drug abuse. Its visibility and the knowledge of its widespread use to detect drugs served as a great deterrent.

One hundred percent of all urine specimens are tested for the presence of marijuana, cocaine, heroin metabolites, amphetamine, methamphetamine and Ecstasy, and 20-50% of all specimens received are tested for the presence of opiates, oxycodone & oxymorphone and phencyclidine (PCP).[2] Specimens are processed by an Accessioning Department to ensure a strict chain of custody protocol is observed throughout the entire handling process. Specimens are screened using immunoassay testing (qualitative testing) and if no drug is detected, the specimen is reported negative; re-screening occurs if drug is detected upon initial analysis. Two positive qualitative tests result in sampling an original specimen aliquot by the Confirmation Department (quantitative testing) using Gas Chromatography/Mass Spectrometry (GC/MS) technology. Once laboratory certifying officials verify the results, a message is released to the Service Member's command.

The laboratory staff comprises over 60 personnel and continuously produces scientifically valid results. It is the first

Navy lab to process over one million specimens in a single year, FY 2008, and again in FY 2009. The laboratory supports over 2200 military organizations every year. Therefore, the Commanding Officer of such an organization must be an officer capable of managing personnel and equipment in addition to ensuring scientifically valid test results.

Commander, Detachment 3, US Air Force School of Aerospace Medicine (USAFSAM). Commander, Detachment 3, Air Force Institute for Operational Health (AFIOH), now known as USAFSAM, is often commanded by an Air Force (USAF) Colonel (Col) or Lieutenant Colonel (Lt Col). The unit is based at Kadena Air Base, Okinawa, Japan, where the Officer can serve as both the Commander and the Medical Entomology Consultant for the Pacific Air Forces (PACAF). Responsible for overseeing operations as well as providing Medical Entomology and Pest Management consultation to surrounding installations, the Commander's duties include items such as budget management, personnel actions, and representing the organization at meetings.

The primary mission of the Detachment is to promote global health and protect Air Force, Joint Warriors and communities by enhancing readiness and effectiveness. To do this, creative solutions are developed and implemented for operational health problems, using the range of tools available, such as environmental and health surveillance, risk analysis, and technological innovations. The Detachment's capabilities are maximized through the development and utilization of partnerships with domestic and international civilian and governmental entities. As an example, Operation Pacific Angel, a dengue prevention program held in concert with the Philippine Air Force and civilian public health personnel, is a humanitarian and civic assistance program held annually and aimed at improving military civic cooperation between the US, Indonesia, Timor-Leste and Vietnam.

The detachment consists of two divisions: the Consultant Division provides quality consultative and technical support for a variety of program areas in addition to tailored support, including on-site consultation in areas such as Industrial Hygiene, Occupational and Environmental Health, Medical Entomology, Public Health, and Health Physics. The Analytical Division provides laboratory analytical services to help meet project needs and satisfy US Occupational Safety and Health Administration (OSHA), Environmental Protection Agency, and host nation requirements. The Detachment staff consists of biomedical science officers (preventive medicine), a laboratory officer, medical NCOs (technicians), and local nationals. In total, these individuals provide support to nine major Air Force installations in addition to Sister Service organizations across the Pacific Theater, including Japan, South Korea, Guam, Hawaii, and Alaska.

Force Health Protection Officer - Multinational Forces Iraq/US Forces Iraq. In 2009, an Army entomologist, (LTC) deployed to Iraq as the Chief of Force Health Protection. Primary duties addressed force health protection issues through developing, refining and consulting on vector control and pest management; food and communicable disease issues; providing explanations of medical policy for persons (military, civilian, and contractor) being deployed to Iraq; and serving as the leader to resolve water quality issues throughout the theater. This officer also managed the H1N1 (Swine flu) pandemic of 2009, provided oversight to two influenza vaccination programs that fall, and completed the Occupational and Environmental Health Site Assessments (OEHSA) for Iraq. This officer wrote and/or edited various Medical Alerts to educate the population at risk, and he assisted with addressing Congressional inquiries. Medical alerts written during 2009 included: FDA Recalls of Pistachio Nuts, BodyBuilding.com products, Stamina RX, and MRE Dairy Shake Powder, alerts on inhalant abuse (huffing), dust inhalation hazards, rabies, heat injury, etc. The Force Health Protection Officer drafted and coordinated several responses to Congressional Inquiries related to waste management practices, especially burn pits. Animal control is not normally performed by entomologists outside the military, but it is a military entomologist's duty in deployed situations, and this officer managed and resolved animal control issues.

Director, Overseas Laboratory Operation, Walter Reed Army Institute of Research (WRAIR). The Director, Overseas Laboratory Operations, Walter Reed Army Institute of Research, is currently held by an Army entomologist (LTC). As the Director, this officer is responsible for informing the WRAIR Commander of research occurring at the subordinate overseas laboratories, primarily the Armed Forces Research Institute of Medical Sciences (AFRIMS), located in Bangkok, Thailand, and the United States Army Medical Research Unit-Kenya (USAMRU-K) in Nairobi, Kenya.

In the spring of 2011, the AFRIMS laboratory celebrated 50 years of collaborative work with the Royal Thai Army, while USAMRU-K celebrated 40 years of operation, in addition to collaboration with the Kenya Medical Research Institute (KEMRI). The mission of these Army laboratories has evolved to meet the changing needs of the larger medical infectious disease mission and regional requirements.

As Director, this officer must liaise with other DoD agencies that primarily work on global health. In this role, the officer works with the Cooperative Threat Reduction (CTR) Program, a group chartered within the DoD Policy. Initially starting out in the former Soviet Union with a focus to destroy weapons of mass destruction, the CTR Program expanded into other regions and is working toward securing extremely dangerous pathogens (EDPs). The implementer of this program is the Defense Threat Reduction Agency (DTRA). As this expansion is moving primarily into Africa, the Director attends meetings that include the Department of State, United States Agency for International Development (USAID), the Centers for Disease Control and Prevention (CDC), and other US Government agencies with programs in the region. The Director's focus is to ensure that programs are not duplicated and collaborations use WRAIR facilities and existing programs (surveillance, clinical trials, President's Emergency Program on AIDS Relief) to expand global disease surveillance and host nation partnerships. Issues change rapidly and the job requires frequent travel, meetings, and mission and business plan development to foster collaborative global research benefiting both military and civilian populations.

Research Liaison Officer, Deployed Warfighter Protection Program, DoD Armed Forces Pest Management Board. The Armed Forces Pest Management Board (AFPMB) is aligned under Pentagon leadership in the Office of the Under Secretary of Defense for Installations and Environment. The AFPMB formulates policy, provides guidance, and coordinates the exchange of information on all matters related to pest management throughout the DoD. In addition, the Board ensures that environmentally sound and effective programs are present to prevent pests and disease vectors from adversely affecting DoD operations.

The AFPMB consists of three divisions: Operations, Information Services, and Research. The Research Division houses the Research Liaison Officer (RLO)/Program Manager (currently USAF Lt Col) for the Deployed Warfighter Protection (DWFP) program, a DoD-sponsored research grant program administered by the Board. The DWFP is funded at $5.1 million per year with $3 million going to the US Department of Agriculture, Agricultural Research Service, and the remaining $2 million provided annually as a series of competitive grants.

One of the unique aspects of being the RLO is the occasional ability to assist with pesticide and equipment efficacy trials, such as that of the prototype lethal ovitrap evaluation in Key West, Florida, for dengue control. As part of these symposium proceedings, Lt Col Douglas Burkett presented additional information on the DWFP.

Vice Dean, National Military Academy of Afghanistan (NMAA). The NMAA is the crown jewel of college-level education and leader development in Afghanistan. It is a bachelor degree-producing program developed to annually commission new lieutenants that are trained, educated, and inspired in the four pillars of development: academic, military, physical, and character/leader development, all built upon a moral/ethical foundation based on Islam. Graduates set the highest standards of professionalism throughout a lifetime of service to Afghanistan, both in military and civilian leadership positions.

An Army COL served as Vice-Dean, NMAA from November 2009 through June 2010. The duties of Vice-Dean included mentoring the Dean (an Afghan Colonel), 12 Academic Department Heads, the Director of Admissions, and the Director of Instruction (Registrar). The Vice-Dean worked with the Afghans on a daily basis on curriculum, cadet, and faculty development, as well as infrastructure improvement. What makes this position unique is that US, Turkish and Indian mentors develop the faculty, while NMAA cadets receive instruction only from Afghan Instructors.

During 2009, the Academy staff consisted of 318 members. Five academic majors existed during 2010 with12 academic departments consisting of Civil Engineering, Computer Science, Basic Sciences (Physics, Chemistry, Biology, Geography), Mathematics, Foreign Languages, Leadership & Management, Law, History, Religion & Culture, Social Sciences, Military Science, and Physical Education.

The academic program provides a broad liberal education with five majors of civil engineering, computer science, English language & culture, general engineering & science, and legal studies, with leadership & management planned for 2011.

The NMAA cadet’s military training is similar to that of West Point, in that the cadets are on an every-other-day schedule. For instance, they have chemistry class every other day (Saturday, Monday, and Wednesday one week and Sunday, Tuesday, and Thursday the next week; not always Monday, Wednesday and Friday or Tuesday and Thursday like at civilian colleges). The cadets have classes 5.5 days per week with Thursday afternoon and all day Friday (Muslim holiday) off.

The cadets receive leader development opportunities, both in the Officer and Non-Commissioned Officer roles that include leader boards to select top cadets for key assignments. A physical fitness program includes four components of physical education instruction, company athletics, fitness testing and personal fitness. Lastly, the cadets live in an environment of honor and respect, and the Academy as a whole emphasizes character and values in all developmental pillars.

In summary, Army, Air Force and Navy medical entomologists can expect a vast array of multi-faceted opportunities over the course of their military careers - experiences “outside the box” of conventional research, training and education, and unique opportunities to serve both our military and civilian communities.

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The Deployed War-Fighter Protection Program: Developing New Public Health Pesticides, Application Technology, and Repellent Systems

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Abstract. The Deployed War-Fighter Protection research program (DWFP) is an initiative to develop and validate novel methods to protect deployed United States military personnel from vector-borne disease. Starting in 2004 and administered by the Armed Forces Pest Management Board, the program is funded at $5M per year. The DWFP research portfolio is concentrated in 3 specific areas: novel insecticide chemistries/formulations, application technology, and personal protective systems. The program consists of a noncompetitive funding process for USDA-ARS-based research, and a competitive grants process open to non-USDA scientists (PIs from academe, industry, and military entomologists). Up to $3M per year are provided to the USDA-ARS, specifically to National Program 104, dealing with veterinary, medical and urban entomology. The ultimate objective is to find industry partners and get useful products into the market/military stock system. This presentation focuses on DWFP program accomplishments for both the competitive grants and USDA-ARS.

Presentation. Now in its eighth year, the Department of Defense's (DoD) Deployed War-Fighter Protection research program (DWFP) is an initiative to develop and validate novel products and methods to protect deployed United States military forces from threats posed by disease-carrying insects. Lists of the top infectious diseases of military importance show more than half are transmitted by arthropods (Burnette et al. 2008; AMEDD 2010). DWFP research efforts help address these threats and are important for two reasons. First, vector-borne diseases such as malaria, leishmaniasis, dengue, chikungunya, and other arboviruses are among the most important health risks facing deployed troops (Coates 1963; Engleman & Joy 1975; Dickens 1990; CDC 1993, 1994; Newton et al. 1994; Peterson 1995; Sharp et al. 1995; Wallace et al. 1996; Trofa et al. 1997; Withers & Craig 2003; Kotwal et al. 2005; Sanders et al. 2005; Smith & Hooper 2005; Coleman et al. 2006; Debboun et al. 2006; Aronson 2008; Kelly-Hope et al. 2008). For many of these diseases, there are no vaccines or prophylactic drugs available, so preventing human/vector contact is the only protective alternative. Second, insecticide resistance, variable efficacy of insecticides on different species, and a diminishing number of safe, cost-effective pesticides available for control of disease vectors and other public health pests limit options for protection of deployed forces against vector-borne diseases (Gubler 1998; Zaim & Guillet 2002; Aronson 2007; Pridgeon et al. 2008; Xue 2008; Rowland & N'Guessan 2009).

Previous reviews of the DWFP research program (Cope et al. 2008) emphasized contributions by the US Department of Agriculture, Agricultural Research Service (USDA-ARS), Center for Medical, Agricultural, and Veterinary

Entomology (CMAVE) at Gainesville, FL (Linthicum et al. 2007, 2008; Hoel et al. 2010), cooperation between the US Navy Entomology Center of Excellence (NECE) at Jacksonville, FL, and the USDA-ARS Aerial Spray Technology Unit at College Station, TX (Hoffmann et al. 2007a,b, 2009a,b; Farooq et al. 2010, Fritz et al. 2010). This article discusses DWFP competitive grants awarded to academic and commercial collaborators, especially for fiscal years 2009-2010.

Administration and Areas of Emphasis of the Program. The DWFP is administered by the Research Liaison Officer at the Armed Forces Pest Management Board (AFPMB). The program, which was started in 2004, is funded at $5.1 million per year, with yearly increases. It consists of a noncompetitive funding process for USDA-ARS-based research, and a competitive grants process open to non-USDA-ARS scientists. Up to $3 million per year is awarded to USDA-ARS, National Program 104 for Veterinary, Urban, and Medical Entomology. The funds are distributed to 5 laboratories within the USDA: (1) the Invasive Insect Biocontrol and Behavior Laboratory, Beltsville, MD; (2) the Center for Medical, Agricultural, and Veterinary Entomology, Gainesville, FL; (3) the Natural Products Utilization Research Unit, Oxford, MS; (4) the Areawide Pest Management Research Unit, College Station, TX; and (5) the Knipling-Bushland Livestock Insect Research Center, Kerrville, TX. Other collaborators receiving funding from the USDA-ARS through the DWFP include the Navy Entomology Center for Excellence (NECE), Jacksonville, FL, the University of Florida, the Emerging Pathogens Institute, and the Inter-Regional Project 4 (IR-4) of the National Research Service (NRS 2010; Malamud-Roam et al. 2010). For strategic reasons, the DoD has a critical need for the types of research the USDA is uniquely able to provide. In short, it is the intent of the DoD, through the DWFP, to provide funding to the USDA-ARS to reinvigorate a historically important and mutually beneficial working relationship between the DoD and the USDA, particularly as it pertains to DWFP, as defined in formal Memoranda (AFPMB 2003, 2004). As with the competitive grant program, USDA-ARS research products are designed to protect military troops from mosquito- and fly-borne diseases but may also be available to international and US public health agencies and mosquito and vector control districts to prevent disease transmission. Details on the work of these USDA laboratories have been published elsewhere (Core et al. 2005; ARS 2007; Linthicum et al. 2007, 2008; Hoel et al. 2010).

Up to $1.5 million is awarded each year in new competitive grants. The amount available for new starts varies depending on how many projects are carried over from previous years. Grants are awarded for up to $250,000 per year, for up to 3 years. The call for pre-proposals generally goes out each August. Received pre-proposals are reviewed by a 10-member technical committee, consisting of civilian and military representatives of the Army, Navy, Air Force, and USDA-ARS. Based on pre-proposal reviews, investigators may be asked to submit a full proposal. In December, the DWFP Committee convenes for a review of the USDA research conducted over the previous year and to determine the full proposals that will be awarded funding. Final competitive award winners are usually notified in early January.

The DWFP research portfolio is concentrated in 3 specific areas: novel insecticide chemistries/formulations, application technology, and personal protective systems. The first area includes discovery of new active ingredients or the use of existing chemistries formulated and used in new ways against pests and vectors of public health importance. The second area of emphasis includes the development of novel technologies and methods to control insects of public health importance or evaluating existing pesticides and equipment in unique ways. Finally, the third area of interest is to develop new repellent systems, including topical, spatial, and residual repellents that can be used on textiles and other military materials. Most of the grants have focused on chemistries, technologies, and repellents used to control mosquitoes, phebotomine sand flies, and filth flies.

Involvement of the US Department of Agriculture. Although the focus of this presentation is not on the DWFP efforts of the USDA-ARS, they are the most important DWFP collaborator and have a long history of working with the DoD to develop products and techniques for combating vector-borne diseases (Table 1, Knipling et al. 1949; King 1954; McCabe et al. 1954; ARS 1967; Sullivan 1971; Schreck et al. 1978, 1979, 1986). A comprehensive listing of DWFP-related publications for both the USDA-ARS and competitive grant recipients is on the AFPMB web site at http://www.afpmb.org/pubs/dwfp/publications.htm.

Competitive Award Highlights. DWFP requests for pre-proposals yield an average of 30 submissions annually. Submissions come from universities, military laboratories, private industry, foreign governments and other organizations around the world (Table 2). More than one-third of pre-proposals qualify for full proposal submissions, from which 54 were selected for funding during the first 8 years of the program. Among the competitive grants awarded, 43% were for universities, 32% for private industry, and 22% were for US military researchers in various labs at the Walter Reed Army Institute of Research; the US Army Medical Research Institute of Infectious Diseases; the US Army Medical Research Unit-Kenya; the Armed Forces Research Institute of Medical Science, Bangkok; the Naval Medical Research Unit No. 3 (NAMRU-3), Cairo, Egypt; and the Naval Medical Research Unit No. 6 (NAMRU-6; formerly the Naval Medical Research Center Detachment-Peru or NMRCD-Peru). The Australian Army Malaria Institute and two Israeli collaborators also received grants.

The range of topics and quality of the proposals are impressive, and many products have wider applications, outside the military, for public health and veterinary pest control. Awardees are encouraged to seek patents and licensees for their products. Several grantees have completed or are nearing commercialization of their products and including them in the military stock system. The following paragraphs describe several examples of work being undertaken with support from DWFP competitive project grants.

Louisiana State University (LSU), Department of Entomology. Professor Lane Foil and Dr. Tom Mascari from LSU belong to one of two laboratories that have received grants to investigate the use of rodent feed-through techniques (FTTs) to target adult and larval phlebotomine sand flies for the control of zoonotic cutaneous leishmanaisis (ZCL) in the Middle East. The goal of this research is to evaluate novel phlebotomine sand fly control techniques using rodent baits containing a fluorescent dye alone, or in combination with feed-through larvicides or systemic insecticides, to establish the efficacy of different modes of action for controlling sand flies, which live in association with rodents and their burrows (Figure 1).

Table 1. Vector control methods and products resulting from cooperative research between the US Department of Agriculture and the Department of Defense

Vector control methods and products resulting from cooperative research between the U.S. Department of Agriculture and the Department of Defense

1943 - Aerosol valve with pressurized spray-can system

1943 - DDT vs lice, malaria vectors, etc.

1947 - DEET insect repellent

1949 - SIT population suppression

1970s - ULV insecticide spray

1971 - Muscalure for fly control

1977 - BTI biolarvicide vs mosquitoes

1977 - Monomolecular film larvicide

1978 - Permethrin-impregnated fabrics

1997 - Lethal Ovitrap for dengue vectors

2000s - RNAi pesticides (patent pending)

Table 2. Deployed WarFighter Protection Program Competitive Grants, 2004-2011 (n=54); Academia (23), Industry (17), Government (14).

FY / AWARDEE	ORG	PURPOSE	YEARS	HIGHLIGHTS
FY 2004 (n=8): RLO LTC Richard Johnson + DWFP Consultant with ARS-USDA				
CDR David Claborn	**DVECC**	sprayer diesel conversion	1	2 prototypes & NSN for silent backpack
LTC Russell Coleman	**WRAIR**	sand fly control--Iraq	3	improved field operations
LCDR Eric Hoffman	**DVECC**	UAV mosquito control	1	passed to AF
Prof Philip Koehler	**UFL**	filth & biting fly control	3	NSN for imidacloprid fly bait
Dr Robert Peterson	**MSU**	comparative risk analyses	2	public appreciation and several publications
Dr Steven Presley	**TTU**	hollow fiber impregnated fabric	3	novel fiber and non-woven fabric technology
Dr William Reifenrath	**Stratacor**	repellent synergy	(3)	Cancelled
Dr Edgar Rowton	**WRAIR**	sand fly control--Lab	2	essential collaborative service
FY 2005 (n=7): RLO CAPT Gary Breeden				
Prof Charles Apperson	**NCSU**	dengue vector ovitrap	2	DUINS student; Gates grant for development
Prof Lane Foil	**LSU**	targeted sand fly control	3	lab proof-of-concept
Capt Karl Haagsma	**YARS**	mosquito control with UAV	(2)	passed to USDA-ARS-APMRU

Dr Que Lan	**UWM**	novel IGR mosquitoes	3	publications: product licensed to Clarke MC
Dr Michael Scharf	**UFL**	LMW insecticides	3	industry support
LT Jeffrey Stancil	**NAMRU-6**	dengue vector larval control	3	autodissemination method; PNAS publication
Alon Warburg	**HUJI**	sand fly control military camps	3	indoor repellent dispenser evaluations
FY 2006 (n=6): RLO CAPT Gary Breeden				
Bruce Dorendorf	**DAT**	diesel backpack mistblower	2	gas powered prototype (not diesel)
Bruce Dorendorf	**DAT**	ULV nozzle	2	NSN commercial ULV sprayer
David Malone	**Adapco**	new ULV adulticide	2	EPA registration and NSN
Dr Phil Kaufman	**UFL**	novel compounds vs Diptera	3	novel chemistry inventions, publications
Dr Robert Peterson	**MSU**	comparative risk analyses	2	strategic appreciation
Dr Gaby Zollner	**WRAIR**	metofluthrin spatial repellent	2	tent protection evaluations
FY 2007 (n=3): RLO CAPT Stanton Cope				
Dr Edgar Rowton	**WRAIR**	sand fly control—WRAIR Lab	1	essential collaborations
LT Jason Richardson	**USAMRU-K**	sand fly insectary, USAMRU-K	1	African field testing facility
Drs Dolan & McAllister	**CDC-NCZVED**	natural product pesticides	1	CDC partnership for carvacrol, nootkatone, etc.
FY 2008 (n=10): RLO CAPT Stanton Cope				
Bruce Dorendorf	**DAT**	ULV backpack system	2	prototype U-BLAS-1 ready for licensing
Prof Lane Foil	**LSU**	sand fly larval control	3	field proof-of-concept and several publications
MAJ Stephen Frances	**AAMI**	Australia field repellent fabrics	2	tent treatments
Philipp Kirsch	**Aptiv**	adulticides targeting sand flies	(2)	Defaulted
Prof Philip Koehler	**UFL**	military protection vs filth flies	3	fly trap patent pending: commercial partner
Richard Poché	**Genesis**	host-target insecticide vs sand flies	2	field trials feed-through rodent bait
LT Jason Richardson	**AFRIMS**	novel strategies vs *Aedes aegypti*	2	pyriproxyfen dispersal in tunnel tests
Dr Masoud Salyani	**UFL**	spray characterization for sand flies	2	aerosol behavior in hot arid environment
Prof Alon Warburg	**HUJI**	phlebotomine control	3	field deployable insecticidal barrier fence
Dr Michael Willis	**Clarke MC**	formulate larvicide & find synergist	2	JME publication; synergist discovery
FY 2009 (n=5): RLOs CAPT Stanton Cope & Lt Col Douglas Burkett + NECE Liaison Officer posted at MFRU-CMAVE-ARS-USDA Gainesville, FL				
Michael Banfield	**Springstar**	lethal ovitrap development	2	Licensed, FLC tech transfer winner
Eyal Ben-Chanoch	**Beeologics**	dsRNA production	1	MFRU lab application proof of principle
Prof Lane Foil	**LSU**	travel funds for previous award	3	extended FY 2011
Amir Galili	**Westham**	ATSB for sand flies	1	extended FY 2011
Doug VanGundy	**CLS**	etofenprox ULV airspray for EPA	1	EPA registered, pending all-crop MRL tolerances
FY 2010 (n=6): RLO Lt Col Douglas Burkett + Public Health Pesticide Manager IR-4 position created for Regulatory support				
Prof Jeffrey	**UFL-EPI-**	Insecticide invention	5	augmenting Gates & FNIH low hazard

Bloomquist	**Ento**			carbamates
Bruce Dorendorf	**DAT**	temperature controlled nozzle	1	flow rate standardization
Amir Galili	**Westham**	ATSB dispenser	1	multiple application systems
Prof Randy Gaugler	**CVB Rutgers**	pyriproxyfen vs *Aedes albopictus*	2	area-wide trials; autodissemination station
Dr Laor Orshan	**MoH Israel**	ATSB actives	2	lab tests, multiple actives
Richard Poché	**Genesis**	rodent feed-thru vs sand flies	2	larvicide and systemic adulticide
FY 2011 (n=9): RLO Lt Col Douglas Burkett				
Dr James Austin	**BASF**	residual Rx military fabrics	3	new insecticides; major formulation effort
Bruce Dorendorf	**DAT**	centrifugal radial flow compressor	2	hyper-efficient spray technology
Prof Lane Foil	**LSU**	sand fly larval control	1	African field trials
Amir Galili	**Westham**	ATSB delivery sand flies	1	preferred system field trials
Prof Graham Matthews	**IPARC**	electrostatic sprayers	2	enhanced targeting, reduced wastage
Nitzan Paldi	**Beeologics**	dsRNA delivery & environmental fate	3	pioneering development of new biopesticide class
Prof Robert Peterson	**MSU**	optimizing ULV effectiveness	2	minimizing ULV risk
Dr Edgar Rowton	**WRAIR**	repellents & infected vector behavior	3	crucial vector/pathogen evaluation vs repellents
Dr Michael Willis	**Clarke MC**	IRS mixture formulation	3	novel IRS mixture vs resistant vectors

Acronyms: AAMI = Australian Army Malaria Institute; AF = Air Force; AFRIMS – Armed Forces Research Institute of Medical Sciences; ARS = Agriculture Research Service; ATSB = attractive toxic sugar bait; BASF = Baden Aniline and Soda Factory; Capt = Captain in US Air Force; CAPT = Captain in US Navy; CDC-NCZVED = Centers for Disease Control and Prevention – National Center for Zoonotic, Vector-Borne and Enteric Diseases; CDR = Commander in US Navy; CLS = Central Life Sciences; CVB = Center for Vector Biology; DAT = Dorendorf Applied Technologies; dsRNA = double-stranded ribonucleic acid; DUINS = duty under instruction; DVECC = Disease Vector Ecology & Control Center of the US Navy; DWFP = Deployed War-Fighter Program of Research; EPA = Environmental Protection Agency; FL = Florida; FLC = Federal Laboratory Consortium; FNIH = Foundation for the National Institutes of Health; FY = Fiscal Year; HUJI – Hebrew University, Jerusalem, Israel; IGR = insect growth regulator; IPARC = International Pesticide Application Research Centre; IR-4 = inter-regional program #4 of the USDA; IRS = indoor residual spray; JME = Journal of Medical Entomology; LCDR = Lieutenant Commander in US Navy; LMW = low molecular weight; LSU = Louisiana State University; LT = Lieutenant in U.S Navy; LTC = Lieutenant Colonel in US Army; Lt Col = Lieutenant Colonel in US Air Force; MAJ = Major in US Army; MC = Mosquito Control; MFRU-CMAVE-ARS-USDA = Mosquito & Fly Research Unit – Center for Medical, Agricultural & Veterinary Entomology – Agricultural Research Service – United States Department of Agriculture; MoH = Ministry of Health; MRL = minimum residue level; MSU = Montana State University; NECE = Navy Entomology Center of Excellence; NAMRU-6 = Naval Medical Research Unit-6, Peru; NSN = National Stock Number; PNAS = Proceedings of the National Academy of Sciences; RLO = Research Liaison Officer; RNAi = ribonucleic acid interference; TTU = Texas Tech University; UFL-EPI = University of Florida – Emerging Pathogens Institute; UAV = unmanned aerial vehicle; ULV = ultra-low volume; USAMRU-K = United States Army Medical Research Unit – Kenya; USDA-ARS-APMRU = United States Department of Agriculture – Agricultural Research Service – Area-Wide Pest Management Research Unit; WRAIR = Walter Reed Army institute of Research; U-BLAS-1 = Ultimate-Backpack Liquid Atomization System-One;
YARS = Youngstown Air Reserve Station, with 910th Airlift Wing.

To date, LSU has received three DWFP grants and produced numerous publications: Foil & Mascari 2010; Mascari & Foil 2009, 2010a-d; Mascari et al. 2007a,b; 2008. Initial work focused on laboratory and field studies using the FTT as a larvicide contained in rodent droppings and as a systemic for adult sand fly control.

Field studies showing proof-of-concept were conducted in Kenya and Egypt to evaluate FTT's for larval and/or adult sand fly control.

Field studies conducted in conjunction with the US Army Medical Research Unit in Kenya (USAMRU-K) using a fluorescent tracer dye showed larvae of the primary leishmaniasis vector in the study area, *Phlebotomus duboscqi*, did not feed on the feces of the local burrowing rodents and hence could not be used as a control technique against the sand fly larvae.

Figure 1. Images from Mascari and Foil 2009 showing a blood-fed female sand fly taken under incandescent lighting and by fluorescence microscopy. The sand fly took a bloodmeal from a hamster fed a diet containing rhodamine B. Early work leading to laboratory proof-of-concept for feed-through technique as a viable technique for sand fly control. Photos: T. Mascari.

However, the results showed that *Ph. duboscqi* takes blood meals from target reservoir rodents (*Mastomys* sp., *Tatera* sp., *Taterillus* sp.), indicating that the FTT might be used as part of an integrated control program for the adult sand flies. Several systemic compounds were evaluated in the lab, including ivermectin, abamectin, imidacloprid, and spinosad. Ivermectin provided the best results, about 7 days of control for adult blood-feeding sand flies (Mascari & Foil 2010c). Feed-through larvicides tested against larvae include diflubenzuron, pyriproxyfen, ivermectin, and novaluron.

In 2010, field trials were conducted in Libya to evaluate the FTT against *Ph. papatasi* and the *Leishmania major* reservoir, *Psammomys obesus* (fat sand rat) with promising results. Here, a suitable rodent bait containing insecticides was developed and eagerly consumed by wild fat sand rats. Tracer dyes were used in these trials and showed the sand fly larvae were consuming the rodent feces in the burrows and the adult sand flies were taking blood meals from the local rodents. For this sand fly species and local rodent population, the FTT could potentially be used for adult and larval sand fly control. Field trials to evaluate the efficacy of the FTT on field populations of *Ph. papatasi* are scheduled to begin in the spring of 2011.

Dr. Foil's research group conducted laboratory tests incorporating various insecticides (boric acid, imidacloprid, ivermectin, or abamectin) into sugar baits as oral toxicants for adult *Ph. papatasi*. This work concluded that imidacloprid, ivermectin, or abamectin could all be used to control adult sand fly populations with targeted use of insecticide-treated sugar baits (Foil & Mascari 2010). A small-scale field evaluation of the toxic sugar solutions containing a fluorescent tracer dye to mark nectar-feeding adult male and female *Ph. papatasi* is also planned for the spring of 2011.

Genesis Company (Wellington, Colorado). In the other DWFP-funded effort to evaluate the FTT for control of phebotomine sand flies, Richard Poché and colleagues at Genesis Company demonstrated proof-of-concept in the laboratory and developed palatable baits for burrowing rodents of the Middle East that serve as local reservoirs for zoonotic cutaneous leishmanaisis (Poché 2010a,b; Poché et al. 2011 (unpublished data); Ingenloff et al. 2011 (in press); Wasserberg et al. 2011 (in press)). Genesis has an EPA registration for Kaput®, an award-winning imidacloprid-based product used for flea and plague control on rodents in the western United States. Recently, five studies evaluated FTT effectiveness in sand flies using fat sand rats and jirds (*Meriones* sp.). Several insecticides were found to be highly effective against both larval and adult *Ph. argentipes* when delivered by feed-through baits, some with long-lasting efficacy both as a larvicide in rodent feces and systemic adulticide against blood-feeding adults, with quick knockdown at dosages as low as 50 ppm. Field efficacy trials are scheduled for the Middle East during the spring of 2011. Next steps include pursuing EPA registration of a rodent bait containing fipronil, which could either be initially labeled for sand fly control or extended for that usage. Results indicate that an effective bait can be developed for integrated sand fly control strategies of value to the military in regions endemic for ZCL.

Dorendorf Advanced Technologies (DAT LLC) (Winnebago, MN). A small engineering company, DAT, is owned by Bruce Dorendorf who has been awarded 5 DWFP grants. These grants resulted in three awarded patents (Dorendorf, 2009, 2006, 2004) and two patents pending. This includes the ADAPCO innovations for commercial spray equipment; two of these machines have been awarded National Stock Numbers (NSN) and are in the military stock system. Earlier DAT grants focused on developing (1) a new diesel-powered ultra low volume (ULV) truck-mounted sprayer now being distributed by ADAPCO (Terminator™), and (2) a military backpack compressed air powered backpack sprayer (JQSX) that silently delivers a constant flow rate and consistent droplet spectra for residual applications (Figure 2).

These sprayers were designed to be compatible. The Terminator™ ULV machine has a built-in air compressor that can be used to charge air cylinders that power the JQSX silent backpack sprayer. Additionally, the Terminator™ ULV has a unique high-pressure nozzle designed and patented by DAT that improves droplet spectra for ULV applications. Both sprayers have military NSNs, and the Terminator™ ULV is a standard item in the Navy's preventive medicine deployment kits.

Figure 2. Compressed air powered backpack sprayer (JQSX) that silently delivers a constant flow rate and consistent droplet spectra. This silent sprayer now has a military stock number and is designed to be compatible with the diesel Terminator™ ultra low volume (ULV) truck-mounted sprayers. Several commercially available sprayers incorporate significant nozzle and other design modifications developed by Dorendorf Advance Technology via DWFP to improve application. Photo: T. Walker.

More recently and in conjunction with the annual NECE "equipment rodeo," where various manufacturers of spray equipment simultaneously characterize their equipment against one another, DAT tested a prototype high performance ULV backpack sprayer called the U-BLAS-ONE (Figure 3). The U-BLAS-ONE sprayer contains a unique high-performance nozzle patented by DAT for DWFP that produces droplet spectra as good as the best truck-mounted ULV machines (Walker 2010).

The DAT also has a grant to develop a space spray machine that possesses the best properties of both ULV and thermal fog sprayers. This unit has the potential to improve droplet spectra and improve insecticide efficacy for space spray vector control operations. The DAT's innovative and purpose-built products epitomize the mission of the DWFP program by providing battlefield-ready vector control spray equipment and innovation for use by deployed warfighters at a reasonable cost.

Rutgers University, Center for Vector Biology. Three DWFP projects utilized pyriproxyfen, a powerful insect growth regulator (IGR), against *Aedes aegypti* and *Ae. albopictus*. First in the Peruvian Amazon community at Iquitos, where *Ae. aegypti* transmits multiple serotypes of dengue, NAMRU-6, with local collaborators and colleagues from UC Davis and Rothamsted Research, U.K. (Sihuincha et al. 2005; Devine et al. 2009), demonstrated the field effectiveness of the autodissemination method proposed by Itoh et al. (1994), whereby pyriproxifen was carried by female mosquitoes from their resting sites to oviposition sites where they transferred sufficient toxicant to prevent the breeding of *Ae. aegypti*. This technique is appealing due to its potential for treating concealed breeding sites not otherwise locatable. Building on the 'proof of principle' in Peru, military entomologists at AFRIMS, Bangkok (Evans et al. 2009; Richardson 2010 (unpublished data)), successfully evaluated the autodissemination technique as a practical control strategy for *Ae. aegypti* in Thailand.

Dr. Randy Gaugler, Director of the Rutgers University Center for Vector Biology, received a DWFP grant entitled "Practical Strategies for Using Pyriproxyfen Against the Asian Tiger Mosquito, *Aedes albopictus*." The Rutgers grant will evaluate pyriproxyfen treatments in urban New Jersey by autodissemination using backpack sprayer applications, to assess the area-wide feasibility for controlling *Ae. albopictus.* The Mosquito Abatement Districts (Hudson County Mosquito Control, Mercer County Mosquito Control, Monmouth County Mosquito Extermination Commission) are implementing this project with regulatory support by the IR-4 project, which serves to supplement the USDA-funded Area-Wide Pest Management Program for the Asian Tiger Mosquito in New Jersey (USDA-ARS 2008). NECE has parallel experiments with DWFP funds to replicate the Rutgers project with pyriproxyfen against *Ae. albopictus.*

Figure 3. The prototype ULV backpack sprayer (U-BLAS-ONE) built by DAT was evaluated in February 2010 during the annual "equipment rodeo" conducted by the Navy Entomology Center of Excellence. The U-BLAS-ONE gave a droplet spectrum equivalent to the best truck-mounted ULV machines. Photo: T. Walker.

Results to date are mixed but reasonably encouraging. Applications were made using a checkerboard backpack sprayer application to 5% of homes in several urban residential areas in Mercer and Monmouth Counties, NJ (Figure 4).

Likewise, promising results were seen for applications made to centralized tire piles and then monitoring autodissemination and dispersal of pyriproxyfen concentric rings radiating out from the treatment site. One of the more exciting aspects of this work was the submission of a recent patent for an autodissemination ovitrap that incorporates pyriproxyfen. The trap is designed to make use of the "skip oviposition" behavior of container-inhabiting mosquitoes and incorporates the autodissemination technique as a means of treating breeding sites, especially those that are cryptic and otherwise difficult to locate and treat.

Field trials with an expanded EPA experimental use permit are scheduled for 2011 in NJ and FL. To date, NECE has conducted the pyriproxifen-related droplet and swath characterization trials using various spray equipment and is planning parallel tire pile and ovitrap evaluation field work in FL to compare the results obtained in NJ.

Figure 4. A DWFP grant to Rutgers University, Center for Vector Biology, is looking at strategies for using pyriproxyfen against *Aedes albopictus*. Work includes using a "checkerboard" application pattern in a New Jersey residential area (shown), tire pile treatments, and autodissemination stations. Photo: Randy Gaugler.

Westham Innovations and other DWFP grants on Attractive Toxic Sugar Baits (ATSBs). DWFP grants have been awarded to several researchers for evaluating ATSBs to control phlebotomine sand flies, vectors of leishmaniasis. Amir Galili (Westham Innovations) with academic colleagues Gunter Müller and Yosef Schlein (funded separately by the Bill and Melinda Gates Foundation) have been working to develop ATSBs that are effective against sand flies and mosquitoes (Müller & Schlein 2006, 2008, 2011; Xue et al. 2006, 2008, Xue 2008; Müller et al. 2008, 2010a,b,c; Schlein & Müller 2008, 2010; Junilla et al. 2011). The hope is to develop suitable formulations and ATSB dispensers or barriers for use around military installations and housing to protect people against foraging flies. Preliminary efforts by Schlein and Müller have demonstrated remarkable efficacy of ATSBs with boric acid and spinosad insecticides against sand flies when applied as a barrier on vegetation, low fences, or bait stations (Figure 5). Initial field proof-of-concept experiments showed that ATSBs caused drastic reductions of sand fly populations in treated areas.

Continuing DWFP-funded efforts using ATSBs are looking at (1) various formulations and active ingredients; (2) measuring attraction distance of different carriers, such as bait stations or pellets soaked/coated with ATSB; (3) the influence of surface area size for attraction distance; (4) the effect of dust burdens on the efficacy of ATSB; (5) suitable time intervals in which ATSB should be re-applied; (6) improved bait formulation completely based on dry components, which only need the addition of water prior to use; (7) improved bait station function and use of hollow pellets in dusty areas; and (8) evaluating the impact of ATSB on non-target organisms in the field and laboratory. Thus, we are hopeful that an EPA-approved ATSB product could become available for military and general public health use.

Figure 5. Field application of an attractive toxic sugar bait for adult phlebotomine sand fly control. Photo: Amir Galili.

Laor Orshan of the Israeli Ministry of Health, collaborating with Gabriella Zollner at Walter Reed Army Institute of Research, also have DWFP grants to look at the efficacy of ATSBs. Early results found several insecticides that were efficacious (Orshan & Zollner 2010 (unpublished data)), but need to be evaluated in the field. Likewise, laboratory work by Allan (2011) with mosquitoes and by Foil & Mascari (2010) with *Ph. papatasi* sand flies found several promising insecticides for use in ATSBs, with boric acid generally showing disappointing results.

University of Florida, Department of Entomology and Nematology. Filth-breeding flies are a ubiquitous pest and potential disease vector during military deployments (Goddard 2008, Pehoushek et al. 2004). Available filth fly control measures, such as baited traps, ultraviolet light sources, and space and residual sprays, all have their limitations, and none provides 100% control when used alone (AFPMB 2006). Earlier work in Koehler's Urban Entomology Laboratory helped facilitate the registration of an imidacloprid-based paint-on insecticide that is now available in the military stock system.

Through some innovative work at the University of Florida, one additional filth fly killing tool was developed and called the fly attractant system with toxicant treated cords (FAST-TC). Initial lab and field tests were so impressive that a licensing agreement with Killgerm Corporation was signed to enable the production of FAST-TC (Diclaro et al. 2009, Koehler et al. 2010, DeFranco 2010).

The FAST-TC is constructed using a visually attractive blue corrugated plastic background with black lines made from insecticide (imidacloprid)-treated wool cord (Figure 6). Yellow has long been thought to be the preferred trap color for filth flies (DiClaro 2010). Comparison of the behavioral and physiological responses of house flies shows a direct correlation of attractiveness to visual targets and the intensity of neurological response. Yellow, however, was the exception. Yellow was repellent to house flies, but it triggered a relatively high neurological response. Filth fly control continues to be a problem for the military and a priority for DWFP. Other relevant DWFP filth fly work includes publications by Geden et al. 2009, Geden 2006, 2005, Mann et al. 2010, Turell et al. 2010, and Chaskopoulou et al. 2009. Future aerial application and sand fly control work is planned with Phil Koehler's post doc student, Alex Chaskopoulou, who will be conducting lab and field trials in Greece and throughout the Middle East over the next 3-4 years.

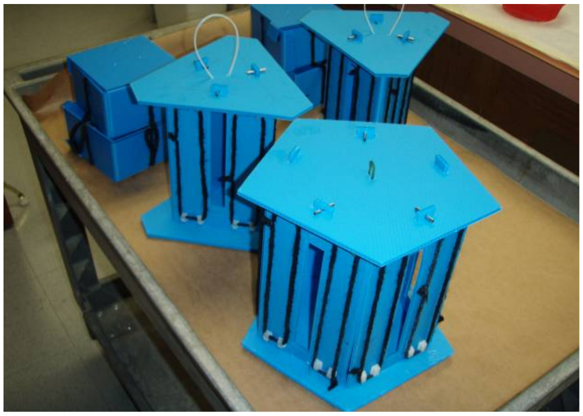

Figure 6. In 2010, University of Florida, Urban Entomology Lab (Phil Koehler) signed a licensing agreement with Killgerm Corporation to begin commercial production of a fly attractant system with toxicant-treated cords (FAST-TC) designed to attract and kill a variety of filth fly species. Photo: J. DiClaro.

SpringStar, Inc., Licensed Development of a Lethal Ovitrap (LOT) for Dengue Vector Control. Because dengue is more widespread globally than any other vector-borne disease (WHO, 2011), and the current pandemic of dengue continues unabated with about 100 million human cases annually (www.cdc.gov/dengue) in some 125 countries, our troops have increased requirements to guard against dengue transmission by container-breeding *Aedes aegypti*, *Ae. albopictus* and *Ae. polynesiensis*. The AFPMB (2011) is producing a pocket guide for dengue vector control. Although dengue was eliminated from the USA during the 1940s, this disease has reappeared in Florida recently (CDC, 2010). The outbreak began in 2009 with almost 100 cases of locally transmitted dengue fever in Key West (Florida, 2010).

Reappearance of dengue in the USA gave an opportunity and incentive for field deployment and evaluation of the Army patented lethal ovitrap (LOT) for dengue vectors (Perich & Zeichner 1999, 2001, 2002), recently licensed to Mike Banfield, owner of SpringStar, Inc., for development, production, and worldwide marketing. After initial laboratory testing (Zeichner & Perich 1999), the LOT system was evaluated in Brazil (Perich et al. 2003), Thailand (Sithiprasasna et al. 2003) and Australia (Ritchie 2005, Ritchie et al. 2009) with mixed results. The SpringStar LOT has a bifenthrin-treated ovistrip for killing female mosquitoes when they alight to oviposit, and to prevent their progeny from developing in the LOT water (Figure 7). Beginning July 2010, in collaboration with the US Army Public Health Command, NECE, AFPMB, and local Naval Air Station volunteers, approximately 7,000 LOTs were placed in Old Town Key West. These LOTs were checked fortnightly for the presence of mosquitoes, while the local dengue vector *Ae.aegypti* population was monitored and subjected to intensive control measures. Results showed a need to further refine the insecticide formulation and ovistrip in the LOT. Additional field trials are planned to evaluate the LOTs against field populations of *Ae. albopictus*. In January 2011, Walter Reed Army Institute of Research and the US Army Public Health Command, which initially developed the LOT, were selected as joint winners of the Federal Laboratory Consortium 2011 Award for Excellence in Technology Transfer.

Conclusion. Success of the DWFP research program has been largely due to the synergy amongst its collaborators in both the competitive and USDA-ARS portions of the program. The diverse portfolio of projects includes techniques for killing disease vectors, new insecticide chemistries, and research into various types of repellents. While many useful products from DWFP research are now available in the military stock system, and others are on the way toward production, the examples described in this paper are far from sufficient to cover all DoD needs. Apart from combating mosquitoes and other flies that transmit debilitating diseases, there are many other medically important arthropods that merit our concern. With nearly 8 years of progress in the DWFP program, the focus remains on the most important military vectors of disease, particularly certain species of mosquitoes, sand flies, and filth flies.

Many of the grants discussed in this paper will continue to receive DWFP funding in 2011. New grant recipients for 2011 include BASF Pest Control Solutions, looking at several compounds and formulations on military materials; Montana State University, for risk assessment work; the International Pesticide Application Research Centre (IPARC), investigating electrostatic sprayers; Clarke, for some new residual insecticide chemistries; Walter Reed Army Institute of Research, working on whether or not infected vectors are affected by standard repellents; and Beeologics, LLC, for additional work on formulating the molecular pesticide RNAi.

The US military has worked closely with a variety of partner organizations to develop a range of vector control and vector identification techniques. Partner organizations include military forces, other US governmental organizations, such as the EPA and CDC, and commercial businesses. In many instances, the US military supplied funding and motivation to other organizations (notably the IR-4 project and the USDA) to develop products, and has subsequently tested and fielded these products, several of which play a significant role in protecting deployed US military forces from arthropod-borne diseases.

Figure 7. DWFP-funded field trials continue to evaluate the efficacy of a prototype lethal ovitrap (LOT) now being produced by SpringStar, Inc., for control of container-inhabiting *Aedes* mosquitoes. In January 2011, Walter Reed Army Institute of Research and the US Army Public Health Command were selected as a winner of the Federal Laboratory Consortium (FLC) 2011 Award for Excellence in Technology Transfer. Photo: SpringStar.

Continued research and development with a range of partners is essential, as no single vector control product can completely control all vectors under all circumstances. Effective control of vectors often requires employment of multiple products and measures for integrated vector management (WHO, 2011). History shows that many of the most important vector control methods and materials were discovered and developed by collaborative efforts between the DoD and the USDA, then commercialized for public health benefit as well as business success. Thus, we are confident that the DWFP program will yield even more innovative product developments to combat vector-borne diseases in our military forces.

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Switch Hitting: Protecting the WarFighter at Home and Abroad

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Abstract. Force Health Protection begins in garrison well before the warfighter goes “down range.” As a Navy civilian entomologist and a Navy reserve entomologist and medical planner, the presenter has a unique perspective in providing medical entomology and pest management services to Sailors and Marines, enabling them to perform their contingency mission before they leave home. Navy and Marine Corps installation pest management operations not only protect personnel and their families, they ensure realistic combat training, a high quality of life in garrison, and training for deployable preventive medicine units. Some programs, such as vector control, are obvious force multipliers, while others, such as invasive weed control and wildlife damage management, are not so obvious contributors to National Defense. These programs contribute to the readiness of our military to defend our country anywhere, anytime.

Presentation. Force Health Protection begins in garrison well before the warfighter goes “down range.” As a Navy civilian entomologist and Navy reserve entomologist and medical planner, the author has a unique perspective on providing medical entomology and pest management services to sailors and Marines that enable them to perform their contingency mission before they leave home.

The Naval Facilities Engineering Command Southwest Applied Biology Program provides specialized Integrated Pest Management support to Navy and Marine Corps installations in the western US. Installation pest management operations not only protect personnel and their families, they ensure realistic combat training, a high quality of life in garrison, and training for deployable preventive medicine units. Some programs, such as vector control, are obvious force multipliers, while others, such as invasive weed control and wildlife damage management, are not so obvious contributors to National Defense. These programs ensure the availability of training areas and contribute to the readiness of our military. Examples of specific support include mosquito control and predatory ant management, both collaborative efforts involving Navy Medicine, local and state public health agencies, installation environmental departments, and universities.

The author, a medical planner for US Naval Forces Korea, coordinates Force Health Protection and expeditionary health services support to joint and combined military forces in the Korean Theater of Operations. Pest management issues include vector-borne disease protection and pest control in and around contingency facilities. This entails medical battle watch manning during exercises and contingencies and providing environmental health expertise during engineering site surveys, which is a team effort involving US and Republic of Korea forces.

The Department of Defense’s pest management program extends from the continental US to every part of the world, ensuring that our military is ready to defend our country anywhere, anytime.

DoD Entomological Research and Public Health Contributions to the African Continent

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Abstract. Department of Defense entomologists have had a presence on the African continent for over 60 years in Egypt and 40 years in Kenya, serving in infectious disease-focused research laboratories. The primary mission of the DoD overseas laboratories is to conduct research on infectious diseases endemic to their respective geographic regions that could adversely impact the health of deployed military forces. A secondary and more strategic mission is to improve overall health in host countries. From a security perspective, healthier populations are more productive, leading to stronger economies and ultimately more stable governments. Over the years, the DoD laboratories have made significant contributions in a number of areas, including malaria, HIV, TB, influenza, enteric disease, sexually transmitted infections, arthropod-borne disease, epidemiology, and emerging infectious diseases. Currently, DoD scientists have ongoing projects in 17 African countries. Major focus areas include the President's Malaria Initiative, The President's Emergency Plan for AIDS Relief, and surveillance for leishmaniasis, influenza, enteric pathogens, and emerging infections. Outbreak response and investigation is another area where DoD entomologists have played a significant role, lending their expertise in the investigation of outbreaks across the continent of yellow fever, Rift Valley fever, West Nile fever, Chikungunya, Ebola, and Crimean-Congo hemorrhagic fever. The DoD has also contributed to infrastructure development in Africa, particularly in increasing laboratory capabilities. Over the past 3 years, new laboratory facilities have been dedicated in Tanzania, Kenya, Uganda, and Cameroon to enhance surveillance of emerging infectious diseases. Through DoD programs, hundreds of African scientists have received training from technician to Ph.D. level, building scientific capacity for the partner nations. With the establishment of US Africa Command, DoD entomologists will have a continuing role in addressing security cooperation objectives.

Presentation. Uniformed personnel, civilian employees, and contractors working for the Department of Defense (DoD) have made significant contributions for over 60 years to improving public health on the African continent. The DoD has maintained its involvement in public health activities in Africa primarily through its overseas research laboratories. Both the Navy and the Army currently maintain research laboratories on the continent. Naval Medical Research Unit Number 3 (NAMRU-3) was established in Cairo, Egypt, in 1946, and the US Army Medical Research Unit-Kenya (USAMRU-K) began operations in Nairobi, Kenya, in 1969. Over the past 10 years, satellite laboratories have also been established in Ghana, Tanzania, Uganda, Nigeria and Cameroon.

The DoD overseas laboratories in Africa partner with the host nation, other US Governmental agencies, non-governmental organizations (NGOs), universities, and private industry to conduct their research mission. In addition, personnel from US based DoD laboratories have maintained long-standing collaborations on a wide range of infectious diseases with several African nations (Figure 1).

An early focus of DoD research in Africa was ticks and tick-borne diseases. At NAMRU-3, these efforts were largely overseen by Dr. Harry Hoogstraal (1917-1986), who served over 37 years as head of the Department of Medical Zoology (Figure 2). Dr. Hoogstraal published over 500 papers, directed over 800 research projects and compiled a bibliography of ticks and tick-borne diseases covering over 80,000 publications and spanning 4000 years.

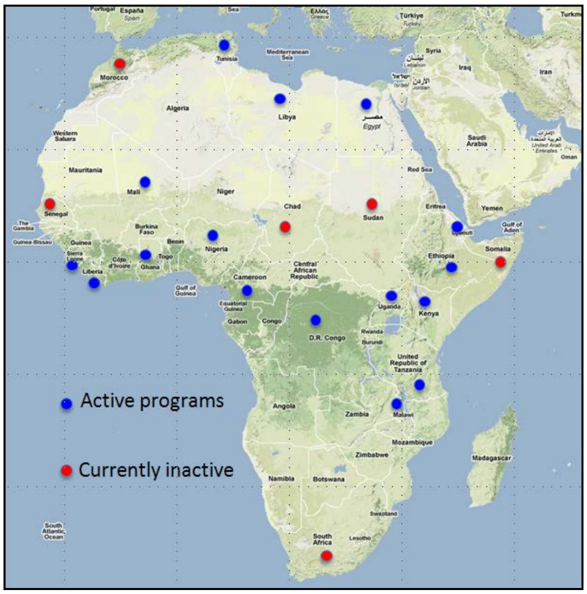

Figure 1. African countries with DoD Entomology and Public Health Programs.

A tick-borne disease of particular interest to the DoD is Crimean Congo Hemorrhagic Fever (CCHF), which is caused by a virus in the family Bunyaviridae, genus *Nairovirus.* This virus, vectored primarily by *Hyalomma* ticks, often causes severe disease in humans, with case fatality rates ranging from 13-50%. The US Army Medical Research Institute of Infectious Disease (USAMRIID) conducted studies on the ecology of CCHF in collaboration with the Pasteur Institute in Senegal between 1986-1991. Human and animal seropositive rates were found to be highest in the northern part of the country and were found to correlate with decreasing precipitation. Overall, 10.4% of 942 sheep and 5.9% 1017 human samples were antibody positive. Eight species of ticks were found naturally infected with CCHF in Senegal, five of which were determined to be probable vectors: *Hyalomma truncatum , H. impeltatum, H. rufipes, Amblyomma variegatum and Rhipicephalus guilhoni.*

Figure 2. Dr. Harry Hoogstraal.

The DoD has played a significant role in advancing knowledge of mosquitoes in Africa. Numerous efforts have been made to expand knowledge of the biology, ecology, taxonomy and control of African mosquitoes, including USAMRU-K studies on the ecology of highland malaria vectors, Walter Reed Biosystematics Unit publications, and Web-based mosquito identification keys and NAMRU-3's efforts to build and strengthen national vector control laboratory infrastructure and capacity in Sudan and Ghana.

DoD scientists have also made significant contributions to the study of numerous mosquito-borne diseases across the continent. Multiple arbovirus epidemics over the past two decades have been investigated by DoD personnel. Among these outbreaks were: yellow fever virus in Kenya (1992/93) and Sudan (2005, 2005); O'nyong-nyong virus in Uganda (1997); Rift Valley fever (RVF) virus in Kenya (1997/98) and Somalia, Kenya, Tanzania (2006/2007); Chikungunya virus in Kenya and the Indian Ocean Islands (2004/2006); and Dengue in Eritrea (2005).

Rift Valley fever, a Bunyavirus in the genus *Phlebovirus,* has been extensively studied by DoD personnel. First isolated in 1931 from sheep during an outbreak near Lake Naivasha in Kenya, infrequent epizootics have since been recorded in a number of African countries, usually correlated with widespread and extended periods of heavy rainfall (Figure 3). Rift Valley fever is primarily a disease of cattle and sheep, but human cases may occur, ranging in severity from mild to fatal. The disease represents a potential catastrophic threat to the US livestock industry if imported. A major RVF epidemic occurred in Egypt during 1977-78, which was intensively investigated by NAMRU-3 and USAMRIID. Estimates of the number of human cases ranged from 18,000 to over 200,000, with at least 598 fatalities. For the first time, four distinct clinical syndromes were described in humans: febrile illness, encephalitis, ocular complications, and hemorrhagic disease.

Army researchers at USAMRU-K conducted a series of studies on the ecology and control of RVF associated with dambos in the Rift Valley of Kenya. Dambos are shallow depressions containing grass and sedge vegetation that, when flooded by seasonal rains, serve as important breeding sites for RVF vectors (Figure 4). Over several years, they found that widespread and prolonged rainfall sufficient to flood dambos leads to hatching of large populations of *Aedes mcintoshi* mosquitoes. Some *Ae. mcintoshi* maintain RVF virus transovarially and, when it is transmitted to cattle and sheep, amplification and spread of virus to secondary vectors occurs, which in turn maintains the epizootic. RVF virus was isolated from numerous species of potential vectors. USAMRU-K scientists also successfully demonstrated that methoprene could be used as a larval control agent in dambos by applying as a pre-treatment or after flooding.

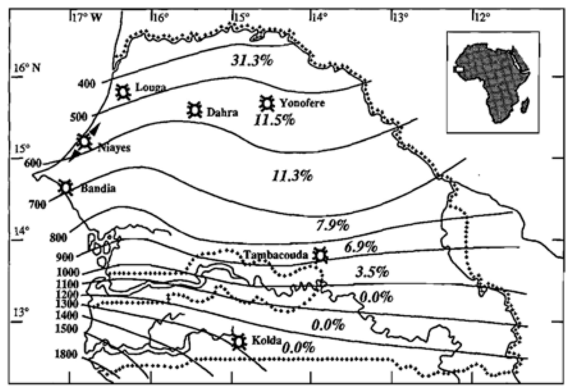

Figure 3. Average prevalence of IgG antibodies to CCHF virus in sheep from mean annual rainfall zones (Wilson et al. 1990).

Figure 4. Flooded dambo in Kenya.

Scientists from USAMRU-K, USAMRIID and NASA developed techniques to use remote sensing technologies to predict RVF outbreaks. Using data from Earth-orbiting environmental satellites that simultaneously measure ocean temperature and vegetation conditions, they demonstrated that the combination of warmer-than-normal equatorial Pacific Ocean temperatures associated with El Niño and rising sea-surface temperatures in the western equatorial Indian Ocean increase rainfall over a large area of eastern Africa, leading to a dramatic green-up of vegetation and increased probability of RVF (Figure 5).

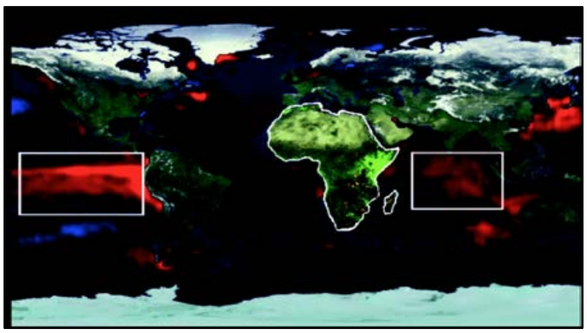

Figure 5. This February 1998 image illustrates the close relationship between ocean temperature (warmer-than-normal ocean temperatures are shown in red, cooler-than-normal temperatures in blue), rainfall, and their impacts on land vegetation (greener-than-normal vegetation shown in light green).

The DoD has had a longstanding interest in malaria because it continues to be a significant problem to residents and visitors to sub-Saharan Africa and presents a significant risk to deployed forces. US military personnel continue to fall victim to malaria during deployments on the continent. US military scientists are currently involved in: malaria drug and vaccine clinical trials, basic science studies on malaria pathogenesis, testing of mosquito repellent products against malaria vectors, and advising malaria control programs as part of the President's Malaria Initiative. To improve malaria diagnostic capabilities on the continent, the US Army Medical Research Unit in Kenya established a Center of Excellence for Malaria Diagnostics in Kisumu, Kenya, in 2004. Since 2004, MDCoE has taught 34 microscopy courses, trained 584 lab techs (40 foreign military) from 18 African countries plus USA and Thailand and established new malaria microscopy training centers in Nigeria, Tanzania and Ghana (Figure 6).

Figure 6. Teaching malaria microscopy in Kisumu, Kenya.

Sand fly biology and control is also a DoD interest in Africa. Entomologists at NAMRU-3 have been involved in assessing the effectiveness of topical repellents against adult sand flies, developing a rapid dipstick assay for detection and identification of *Leishmania* infection in sand flies, characterizing *Leishmania* parasites, conducting epidemiological studies in Libya, determining drug resistance profiles of *Leishmania* parasites, and developing an insecticide resistance test kit for adult sand flies.

In Kenya, USAMRU-K has been conducting research on rodent feed-through strategies for sand fly control in collaboration with scientists at Louisiana State University. Another research effort with the US Department of Agriculture's Center for Medical, Agricultural, and Veterinary Entomology focuses on the use of ULV and residual pesticide sprays for sand fly control. Army entomologists have also been actively involved in conducting surveillance programs for *Leishmania* in Ethiopia, Djibouti, Kenya and Tanzania.

DoD personnel have been on the front line in investigating highly pathogenic viruses in Africa. Ebola and Marburg viruses were extensively studied by Dr. Gene Johnson of USAMRIID in the 1980's. He conducted seminal field epidemiology work centering on Kitum Cave in the Mt. Elgon region of Kenya, searching for the source of Marburg virus following a human infection traced back to the location. As a result of this work, he developed most of the currently used SOPs for working in protective suits under field conditions. A large military team collected over 34,900 arthropods (mosquitoes, ticks, lice, fleas, etc.) in association with a major Ebola outbreak in Kikwit, Democratic Republic of the Congo, in 1995, where 245 of 317 cases were fatal. Despite testing many potential vectors and numerous attempts to locate the natural reservoir or reservoirs of Ebola and Marburg viruses, their origins remain undetermined. However, recent studies indicate the virus can be replicated in some species of bats.

An important mission of USAMRU-K is the testing of drugs and vaccines for malaria and other important infectious diseases. Since 1991, seven Food and Drug Administration (FDA)-compliant vaccine trials have been conducted, involving over 1000 volunteers. USAMRU-K is currently one of 11 sites across sub-Saharan Africa involved in a Phase 3 trial of the malaria vaccine RTS,S, which was originally developed by scientists at Walter Reed Army Institute of Research. Over 1,800 children have been enrolled in this trial and they will be followed for a period of three years. Ten FDA-compliant drug studies have been completed, including a study evaluating Coartem, the current first-line anti-malaria treatment used in Kenya and many other African nations.

Another important DoD-sponsored program is the Global Emerging Infections System (GEIS), which collects surveillance information on a number of important pathogens. Robust DoD GEIS programs are based out of NAMRU-3 and USAMRU-K, covering multiple countries (Figure 7). Current program areas include surveillance for: malaria drug resistance, influenza, enteric pathogens, sexually transmitted infections, acute febrile illnesses, arboviruses, and rickettsial diseases. The DoD GEIS program also builds host nation capacity through enhancing health-related infrastructure and training African scientists.

Figure 7. Ribbon cutting ceremony for new DoD-sponsored Emerging Infections Laboratory in Cameroon.

The President's Emergency Plan for AIDS Relief (PEPFAR) was initiated in 2004 and includes projects in 20 African nations. Supporting PEPFAR, the US Military HIV Research Program has developed comprehensive prevention, care and treatment programs in Kenya, Tanzania, Uganda and Nigeria that provide a platform for HIV vaccine and therapeutics research, epidemiology studies and HIV/malaria and HIV/TB co-infection studies. In 2010, DoD-administered programs were providing services to almost 12 million people.

In conclusion, the DoD has been involved with Entomology and Public Health Programs throughout Africa for over 60 years. DoD scientists have contributed significantly to developing the knowledge base in biology, ecology and epidemiology of tropical infectious diseases. Today, the DoD is actively involved in providing training, enhancing infrastructure, building capacity and conducting research to improve health systems in Africa.

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Navy Entomology in Africa: Building New Partnerships Through Vector Surveillance and Control

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Abstract. The African continent is endemic for many vector-borne diseases with significant public health impact. Established 60 years ago in Cairo, Egypt, U.S. Naval Medical Research Unit No. 3 (NAMRU-3) is a multi-agency platform committed to detecting emerging disease threats of military or public health importance, which is accomplished by collaborating with national, regional, and international partners. NAMRU-3's Vector Biology Research Program (VBRP) studies, monitors, and develops mitigation strategies specifically against regional vector-borne disease threats. VBRP engages with partner countries in three main ways: 1) by providing training, 2) by building capacity and conducting projects in the host country, and 3) by providing support during outbreak situations. Competitively awarded funding from the U.S. Department of State, CDC, AFHSC/GEIS, and MIDRP enables VBRP to execute this mission. In the past calendar year alone, VBRP has: 1) provided vector identification (e.g., sand flies, mosquitoes and ticks) to scientists from Libya and Djibouti, 2) implemented projects to control leishmaniasis in Libya and malaria in Djibouti, 3) conducted a week-long workshop on insecticide resistance attended by entomologists from Sudan, Morocco, and Tunisia, 4) provided training in molecular diagnostics of leishmaniasis, malaria, CCHF, and Rift Valley fever, and 5) directly supported outbreak relief efforts for leishmaniasis in Egypt, malaria in Liberia and the Comoros, and Rift Valley Fever in Sudan. These entomological experiences have enabled the U.S. Navy to cultivate relationships and develop partnerships with many countries that otherwise would not have been possible. Future funding is anticipated as these relationships continue to develop.

Presentation. The US African Command (AFRICOM) was created by President Bush and Defense Secretary Robert Gates in 2007, in part to foster collaborations with African nations to promote regional economic security initiatives. This long-term strategy is to support an environment that is stable and secure for a number of African countries. However, the African continent is highly endemic for many vector-borne diseases that significantly impact public health and stifle economic growth. Management of these diseases remains one of the major obstacles to securing economic and social stability.

The US Naval Medical Research Unit No. 3 (NAMRU-3) in Cairo, Egypt, is a multi-agency platform committed to detecting emerging disease threats of military or public health importance, which is accomplished by collaborating with national, regional, and international partners. Over the past 60 years, NAMRU-3 assisted a number of African countries with health security operations and laboratory capacity building, and assisted in numerous disease outbreak responses. One of the best examples of instituting health capacity and disease surveillance while conducting research has been NAMRU-3's Vector Biology Research Program (VBRP). Over the past five years, the VBRP responded and assisted with a number of disease outbreak investigations throughout Africa, resulting in research collaborations with the ministries of health of Libya, Djibouti, and Liberia. Competitively awarded funding from the US Department of State (DOS) and the Global Emerging Infections System (GEIS) have enabled the VBRP to execute these missions.

In 2008, the DOS funded the VBRP to assist the Djiboutian Ministry of Health (DMH) in developing a mosquito surveillance program to determine the mosquito fauna and potential malaria implications from adjacent refugee camps. In addition, this initiative would provide an important step toward determining major mosquito breeding habitats and assist the DMH in controlling dengue outbreaks the country has experienced over the past five years. Mapping major mosquito breeding sites using Global Information System (GIS) and Remote Sensing (RS) would be most helpful to their mosquito control program. Over the past two years, VBRP staff members have provided training classes in their entomology program on mosquito biology, identification, surveillance, and control (Figure 1).

Figure 1. US Naval Medical Research Unit 3 scientists with members from the Djiboutian Ministry of Health Entomology Department, Djibouti City, Djibouti, February 2010.

Over 20 mosquito traps were placed in Djibouti City and refugee camps in an effort to develop a current country-wide vector distribution map for the DMH.

Recent diplomatic exchanges between the US and Libyan governments facilitated collaborations between NAMRU-3 VBRP and Libya's National Center for Infectious Disease, Prevention and Control Program (NCIDPCP). The NCIDPCP and NAMRU-3 are working on two research projects, one funded by DOS and the other by the Deployed War-Fighter Protection Program. Sand fly surveillance continues to be a major problem for villages near the Mediterranean Sea. In August 2010, NAMRU-3 placed sand fly traps at six sites in the villages of Al Saedek, Al Kefah, and Al Fateh to ascertain specific habitat changes that may cause certain regions to become more favorable for sand fly development. The collaboration between VBRP and the NCIDIPCP proved to be a win-win scenario for all parties involved (Figure 2). In collaboration with Louisiana State University (LSU), NAMRU-3 is testing novel methods for controlling adult sand flies by focusing on disrupting their life cycle at the larval stage. This strategy has the potential for controlling sand flies at their source (rodent burrows), and reducing reliance on other less ineffective control methods, such as truck-mounted spraying.

Across sub-Saharan Africa, malaria is a serious Force Health Protection issue for US troops. Infection rates among unprotected personnel can potentially reach 100 percent. An example of this risk was when members of a Joint Task Force (JTF) serving in Liberia (2003) experienced an extremely high rate of malaria infection. Members who reported spending time ashore had an infection rate of 28% (80/290), while a much higher rate of 44% (69/157) was observed in 26th Marine Expeditionary Unit (MEU) personnel who reported being ashore at night.

Despite the current use of anti-malarial medication, insecticide-treated bed nets, permethrin-treated uniforms, mosquito repellents, and situational awareness briefings, malaria remains a serious risk for US armed forces in Liberia. Holoendemic, with perennial intense transmission, malaria in Liberia accounts for 18% of in-patient deaths, with an estimated annual death rate of 60,000 children under the age of five (Presidents Malaria Initiative, Malaria Operational Plan, FY2010).

Figure 2. Scientists from US Naval Medical Research Unit 3 and the Libyan National Center for Infectious Disease, Prevention and Control Program pose for a photo in Taurgha, Libya, August 2010.

Recently, AFRICOM requested the assistance of NAMRU-3 to investigate a malaria outbreak among US service members deployed to Liberia for Operation Onward Liberty. Members of this operation, in conjunction with the Liberia Defense Section Reform (LDSR), provided mentorship to the Armed Forces of Liberia (AFL). Since December 2009, 15 confirmed cases of malaria, including one fatality, occurred among US personnel. Vector surveillance in this region is nonexistent and little is known regarding anopheline distribution or infection rates by species. Hence, the species of *Anopheles* currently biting US forces and transmitting malaria parasites in Liberia remain unknown.

In collaboration with the Liberian Institute of Biomedical Research (LIBR), the Navy Entomology Center of Excellence (NECE), Walter Reed Biosystematics Unit, and the Presidential Malaria Initiative (PMI), the VBRP collected mosquitoes from four sites in Liberia, and collections from three additional sites are planned for the summer of 2011 (Figure 3). Personnel will use CDC light traps baited with attractants specific for anopheline mosquitoes. They also will collect mosquito larvae at all sites and rear them to the adult stage. Mosquitoes will be sorted, identified to species, the *Anopheles* spp. will be tested for malaria, and their distribution monitored using GIS with RS and molecular techniques. These entomological experiences enabled the US Navy to cultivate relationships and develop partnerships with public health personnel in other countries that otherwise might not have been possible. Future funding is anticipated as these relationships continue to develop, strengthen, and expand among other African nations.

Figure 3. Mosquito technicians from the Liberian Institute for Biomedical Research (LIBR) pose for a picture with US Naval Medical Research Unit 3 staff members at the LIBR facility in Liberia, January 2011.

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Helping to Build Vector Surveillance Programs in the Former USSR

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Abstract. The Defense Threat Reduction Agency (DTRA) Biological Threat Reduction Program (BTRP) supports the development of active and passive surveillance programs focused on especially dangerous pathogens (EDPs), primarily in countries of the former USSR. Many of these EDPs are vector-borne, and Department of Defense (DoD) entomological personnel have been involved in implementing training programs that build capabilities for sustainable programs to enable host-country scientists to conduct EDP surveillance, recognize and report outbreaks, and generate disease risk assessments. BTRP also supports collaborative research projects between host-country scientists, US academic institutions and DoD scientists that aim to determine disease baselines and prevalence and to use these data to develop country-wide risk assessments and predictive maps. Discussion will focus on current efforts in Azerbaijan, the Republic of Georgia, and Ukraine.

Presentation. The Biological Threat Reduction Program (BTRP), part of the portfolio of the Defense Threat Reduction Agency (DTRA), recognized the danger to US national security posed by the threat from dangerous infectious agents. As such, the program addressed this risk by improving the capacity of partner countries to detect and report incidence of these infections and by promoting biological safety and security practices. The first efforts of the BTRP were focused in the former Soviet republics (Figure 1) of Central Asia. The collapse of the Soviet Union left this region vulnerable to the theft, diversion or sale of biological weapons-related material and left a generation of scientists and their associated research on potentially dangerous agents in an unsecure environment. DTRA recognized the value and necessity of facilitating the engagement of partner country scientists and technical personnel as well as that of enhancing partner country capabilities to detect, diagnose and report dangerous infectious agents and to ensure those capabilities were sustainable.

The BTRP efforts focused on a select group of infectious agents from the Health and Human Services' and the US Department of Agriculture's Select Agents and Toxins lists, also called Especially Dangerous Pathogens (EDPs). To achieve the objectives of the BTRP, DTRA partnered with the US Army's premier infectious disease research institutions: the US Army Medical Research Institute of Infectious Diseases (USAMRIID) and the Walter Reed Army Institute of Research (WRAIR). Through these collaborations, Army entomologists became engaged in the program because many of the agents on the EDP list have a vector component (e.g., *Yersinia pestis* (fleas), Rift Valley fever virus (mosquitoes), *Francisella tularensis* (ticks, deer flies), Crimean-Congo hemorrhagic fever virus (ticks)). In particular, the Army entomology engagement was focused within the Threat Agent Detection and Response (TADR) 'product line' of the BTRP.

The TADR program aims to: 1) enhance existing disease surveillance systems in partner countries, to include improving infrastructure, training, and developing new diagnostics; and 2) develop national-level disease reporting protocols/systems. Within TADR, Army entomologists have been instrumental in developing a vector surveillance training program whose mission is to develop or enhance sustainable vector-borne disease threat detection and response programs in partner countries. The training focuses on developing a successful vector surveillance and pathogen diagnostics plan, developing risk prediction and mitigation strategies, and building the capacity of national scientists to develop and perform these activities in an effort to support the TADR/BTRP mission. The training program contains five major subject areas, each with multiple modules: Identification and Biology; Field Collection Techniques; Pathogen Detection; Risk Assessment; and Vector Control and Risk Mitigation. Training in a partner country begins with an in-country assessment, which often includes meetings with the Ministry of Health, senior staff and other personnel from their potentially impacted institutions, as well as lab and field visits. Once a thorough assessment has been conducted, a plan for implementing training is developed that focuses on the specific needs of that partner country, identifying personnel for training, building the vector surveillance team, and developing an outline of future training events.

In the future, TADR will be expanding into the Middle East and East Africa. With this expansion, the vector surveillance program must grow to meet the needs of new partner countries. This may lead to increased involvement in the program by US military entomologists and additional collaborations with other Department of Defense (DoD) organizations (e.g., US Army Public Health Command).

Figure 1. Initial focus of the Biological Threat Reduction Program was in Georgia, Armenia, Azerbaijan, Turkmenistan, Uzbekistan, Kazakhstan, Tajikistan, and Kyrgyzstan.

Protecting the US and Coalition Force in southern Afghanistan

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Abstract. In the summer of 2009, a team of Navy Individual Augmentees formed an 11-person preventive medicine unit to support the expansion of US Armed Forces in southern Afghanistan. This team, modeled after an Army preventive medicine unit, consisted of an environmental health officer, an entomologist, and 9 preventive medicine technicians. Since this was a "first," the team called themselves the 1st Preventive Medicine Detachment, and this designation was used throughout the deployment. Among the many challenges of the deployment, the team was exposed to austere living conditions, overcame cultural differences between the US Services, had the opportunity to provide preventive medicine support to British, Canadian and Dutch Forces, and was able to provide preventive medical instruction to Afghanistan military medical personnel. Faced with multiple challenges, this is a story of lessons learned and success in a Joint Operating Environment.

Presentation. A preventive medicine unit consisting of US Navy Individual Augments was assembled to support US forces expansion in southern Afghanistan in the summer of 2009. The team, consisting of an environmental health officer, a medical entomologist, and 10 preventive medicine technicians, formally became the 1st Preventive Medicine Detachment (1st PMD) (Figure 1). The primary mission of 1st PMD was to support US forces throughout southern and western Afghanistan, including the 5/2 Stryker Brigade Combat Team, the 2nd Marine Expeditionary Brigade, the 82nd Brigade Combat Team, and the Special Forces units. Although the mission was to wholly support US Forces, the 1st PMD worked in concert with preventive medicine allies from the North Atlantic Treaty Organization-International Security Assistance Force (NATO-ISAF), including personnel from the Royal (British) Army, the Dutch Army, and the Canadian Army and Navy. The unit also provided preventive medicine capability training to 40+ Afghan National Army (ANA) medical personnel. Overall, the unit performed 35+ missions, providing service to at least 15 forward operating bases (FOBs) and combat outposts (COPs) throughout southern and western Afghanistan during their 6-month tour, which ended in November 2009.

Upon arrival in theater in May 2009, major preventive medicine issues were identified and included dealing with an extremely limited water supply, improving air quality monitoring, and instigating comprehensive infectious disease prevention programs, such as the prevention of gastrointestinal and vector-borne diseases, and reinvigorating correct sanitation practices.

Figure 1: 1st Preventive Medicine Detachment outside their luxurious living accommodations. Kandahar Airfield, Afghanistan. (Photo: HM1 Andrew Luque)

The most pressing entomological issue was the large population of filth flies caused by inadequate sanitation. In addition, there were endemic vector-borne diseases, such as malaria, leishmaniasis, and Crimean-Congo hemorrhagic fever in the 1st PMD's area of operations (DIA 2010, Safi et al. 2009, AFPMB 2001), and the risk from these diseases as well as appropriate countermeasures had not been adequately briefed to the ground units.

With constant rotations of military personnel, preventive medicine usually gets relegated to a low priority until a disease incident occurs or a situation becomes intolerable and negatively affects military operations. Initially, the 1st PMD had difficulty procuring equipment and supplies to support its mission. In the first few months, the 1st PMD had only one working computer and no work space; however, services and assistance were frequently requested of the team. Despite these limitations, information quickly spread that a unit whose exclusive mission was preventive medicine and public health was in theater. The 1st PMD's operational tempo increased significantly as ground forces realized the usefulness of having an effective sanitation and pest/vector management program available to service their FOBs and COPs (Figure 2).

Figure 2: In southern Kandahar Province, access to some bases was through vast, rugged, desolate desert terrain. (Photo: Travis Cummings).

One of the most significant missions undertaken by 1st PMD was supporting the Jordanian Army. The 1st PMD, along with Army Veterinary Services, investigated a gastrointestinal outbreak among the Jordanian ground forces. The 1st PMD provided subject matter expertise on proper sanitation and food handling practices, which effectively stopped the transmission of gastrointestinal disease among the Jordanian ground forces. The Jordanians showed their gratitude with a feast for the preventive medicine technicians (Figure 3).

In many of the missions accomplished by the 1st PMD, feral and stray animals were a major concern because many units kept pets or mascots. Rabies was a concern since it is relatively common in the Middle East, and there are other complications of keeping pets and mascots in a war zone. Some advocate that unit dogs may have some force protection value, but only if they do not interfere with military working dogs or cause problems that put military personnel at more risk. The least risk method is to follow preventive medicine guidance (Dunton & Sargent 2009) and not permit pets in a war zone.

Figure 3: HM2 (FMF) Darren Miller enjoying the feast provided by the Jordanian Army. (Photo: Ian Estrada).

Malaria is endemic in Afghanistan, although the disease risk is highly concentrated near agricultural areas and in the foothills of the Hindu Kush Mountains in the eastern portion of the country (Safi et al. 2009, Brooker et al 2006), and most military malaria cases have occurred in this area. The 1st PMD's mission was to reduce malaria transmission and other vector-borne diseases in three major FOBs located in Zabul, Kandahar, and Farah Provinces (Figures 4 & 5).

Figure 4: LT Ephraim Ragasa demonstrating Bti application on standing water to medical personnel with the 82nd Brigade Combat Team in a combat outpost in Farah Province. (Photo: Leonard Hayes)

As far as the 1st PMD could determine, this was the first mosquito surveillance in those areas since major military operations began in 2001. The 1st PMD led the investigation of the first documented case of Crimean-Congo hemorrhagic fever in a US service member, and successfully connected local livestock to the disease. The findings led to increased vigilance concerning vector-borne disease surveillance and increased personal protection among US and NATO-ISAF ground forces.

This deployment was a challenging experience for Navy preventive medicine units. Working under the administrative control of a US Army command in a FOB run by NATO presented unique chain-of-command challenges. Nevertheless, the 1st PMD provided the template for future preventive medicine operations in southern and western Afghanistan. The distinctive actions of the 1st PMD led to significant improvements in sanitation as well as a greater awareness of infectious disease risk in theater (Figure 6). These actions were directly related to the mission effectiveness of US and NATO-ISAF Forces.

Figure 5: Lush landscape in an agricultural valley in northern Kandahar Province. (Photo: Leonard Hayes)

Figure 6: HM2 Estela Rojas teaching preventive medicine to Afghan National Army medical personnel. (Photo: Justin Lawrence)

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Air Force Entomology Efforts during Operation Pacific Angel: Philippines, 2010

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Abstract. An Air Force entomologist was deployed to the northern Philippines as part of Operation Pacific Angel in February 2010. Although the broad scope of this mission was to provide humanitarian and civic assistance, the entomologist focused solely on entomological issues and disease prevention within the city of Laoag. A collaborative partnership was built between the USAF, the Philippine Air Force and the Laoag City Health Department to better serve this specific effort. The entomology portion of this mission had three distinct components: First, there was the need to conduct vector-borne disease surveillance in and around the city of Laoag. Thus, mosquitoes and ticks were collected via a variety of methods during this ten-day mission. The specimens were identified and tested for pathogens and viruses, as deemed appropriate. The second component was to provide basic health education to the Philippine populace. The entomologist traveled to 21 barangays within Laoag City and directly spoke to nearly 1,000 residents on the prevention of such common diseases as dengue fever and rabies. Handouts and training aids were also distributed to the residents. The third entomological component of this mission was to provide science-based training to the Laoag City Health Department and the Philippine Air Force on how to establish, among other things, a mosquito surveillance program for their city and military bases. Even though this Philippine mission only lasted 10 days, it was this third component that will have long-lasting implications as the collaborative relationships and partnerships continue to develop and flourish.

Presentation. The Medical Entomologist from Detachment 3, USAF School of Aerospace Medicine (Det 3, USAFSAM), deployed to Laoag City, Philippines, as the subject matter expert (SME) for vector-borne diseases for Operation Pacific Angel 10-1. Operation Pacific Angel is an annual humanitarian and civic assistance program aimed at improving military-civic cooperation between the United States and countries throughout the Asia-Pacific region, and the iteration discussed herein took place 15-22 February 2010. The entomology portion of this mission had three distinct components. First, vector surveillance was conducted in and around the city of Laoag. The second component was to provide basic health education to the Philippine populace, and the third component was to provide science-based training to the Laoag City Health Department and the Philippine Air Force on how to establish, among other things, a mosquito surveillance program for their city and their military. The purpose of this presentation is to detail the findings of the vector survey, which includes a brief discussion of the arthropod specimens collected and the pathogens detected.

Laoag City is the provincial capital of Ilocos Norte and is located in the northwest corner of the Philippines, on the coast of the South China Sea (Figure 1). With a population of over 100,000, Laoag City is the political, commercial and industrial hub of the province. As elsewhere in the Philippines, Laoag City is divided into barangays, which are the smallest administrative divisions of a city. Laoag City has a total of 81 barangays. The city experiences a monsoon climate characterized by a dry season from November to April and a wet season from May to October. This region also occasionally experiences very powerful typhoons. Compared with much of the Philippines, Laoag City has a lower vector-borne disease risk, because of its drier climate. For example, malaria can be severe in some parts of the country but is extremely rare in Laoag City. However, there is still a threat of dengue in this region – a few dozen cases are diagnosed each year and some deaths occur.

Figure 1. Map of the Philippines showing Laoag City in the north.

The following personnel were involved with vector surveys, collections, and disease prevention education: Major Stephen Wolf, Det 3, USAFSAM/CD; Ms Julie Samson, Laoag City Health Department; Ms Laodivin Burgoz, Laoag City Health Department; Ms Ophelia Rodillas, Laoag City Health Department; Col Bernard Bernado, Philippines Air Force, Veterinarian; 1st Lt Grace Ramos, Philippines Air Force, Veterinarian; Ms. Son Yong Yu, American Eatery/Snack Bar; Col Mary Brown, USAF Reserves, RMG Det 15 Veterinarian; CPT Rose Grimm, US Army, 97th CAB Veterinarian.

During the week of 15 February, personnel from the Laoag City Health Department led us to locations of recent dengue prevalence. Over the course of five days, 21 different barangays were visited within Laoag City. Mosquito surveillance was conducted using CDC light traps for adult mosquitoes, dipping for larvae, and ovitraps for eggs (Figure 2). Each day at each location, a CDC light trap was placed near mosquito-breeding sites and in the vicinity of homes. Dry ice was not used because it was not locally available. Ectoparasites, such as ticks and fleas, were opportunistically collected directly from mammalian hosts. Adult mosquitoes were collected each morning and subsequently sent along with the ectoparasites to the US Army Public Health Command Region-Pacific (USAPHCR-PAC) for identification and disease testing. All pathogens found in this survey were detected using real-time PCR technology.

Seventy-five female mosquito specimens from six species and four genera were collected around Laoag City. *Culex annulirostris* and *Cx. quinquefasciatus* accounted for 86% of the total catch, with 44 and 21 specimens collected, respectively. The other four specimens were *Cx. hutchinsoni*, *Anopheles peditaeniatus*, *Armigeres subalbatus*, and *Aedes vexans*. No disease was detected in any of the mosquito specimens. *Aedes* larvae were collected and field identified at various locations but not sent to USAPHCR for specific identification. No eggs were collected in the ovitraps.

Figure 2. Setting a CDC light trap with public health officials outside a home in San Lorenzo.

***Culex annulirostris*.** This species is found in the South Pacific north to the Philippines. Larvae are found in relatively clean water with emergent vegetation. The status of this species as a vector in the Philippines is not known. However, it is a known vector of Bancroftian filariasis in New Guinea and has been implicated in outbreaks of Japanese encephalitis.

***Culex quinquefasciatus*.** This species can be found nearly around the world (i.e., it is cosmopolitan). Larvae can breed in water containing a high degree of organic pollution and development often occurs very close to human habitations. Females readily enter houses at night and bite humans in preference to animals. This species is a vector for filarial nematodes and viruses (e.g., encephalitides) of humans.

***Culex hutchinsoni*.** This species is found in much of southern Asia and the Pacific. It has the ability to breed in extremely polluted waters (e.g., sewer ditches). This mosquito has also been implicated in outbreaks of Japanese encephalitis.

***Anopheles peditaeniatus*.** This mosquito also has zoophilic habits (i.e., it does not preferentially feed on humans). Thus, it is not considered to be an important vector of human disease pathogens. However, *An. peditaeniatus* was found naturally infected with Japanese encephalitis virus in India and falciparum malaria in Sri Lanka.

***Armigeres subalbatus*.** This container-breeding mosquito can be found throughout Asia and prefers polluted waters. Females will bite throughout the day, with peaks at dawn and dusk. It is a known vector of *Wuchereria bancrofti*, the filarial nematode responsible for Bancroftian filariasis.

***Aedes vexans*.** Larvae and pupae are found in unshaded fresh water flood pools in secondary scrub but have also been collected in ditches, swamps and rice fields, usually with little vegetation or algae. Females bite at night and feed primarily on man and cattle. It vectors several encephalitides and dog heart worm.

Three different types of ectoparasites (ticks, fleas, and lice) were collected from dogs, cattle, and carabao during this survey. A total of 109 ticks were collected: 105 specimens of *Rhipicephalus sanguineus* were collected from dogs, and 4 specimens of *Rhipicephalus microplus* were collected from cattle. There was a positive for *Anaplasma platys* in a *R. sanguineus* specimen collected in Barangay 38A, Mangato East. *Anaplasma platys* causes a rickettsia-like disease, known as canine infectious cyclic thrombocytopenia, that affects canines. *Haematopinus tuberculatus*, the water buffalo sucking louse, was collected on carabao at two locations. One of the 34 lice collected, specifically from Barangay 1 (San Lorenzo), had a very weak positive test for *Rickettsia felis*, a pathogen responsible for spotted fever in humans. At Barangay 1 and Barangay 38A, two fleas, *Ctenocephalides felis*, were collected from dogs (one from each dog) and both tested positive for *Rickettsia felis*.

***Rhipicephalus sanguineus*.** The brown dog tick can be found around the world. This extremely common tick feeds on dogs during all three developmental stages. However, it will occasionally bite humans and is a vector of several types of spotted fever. This tick is a significant vector of spotted fever *Rickettsia*, *Ehrlichia canis*, *Hepatozoon canis*, *Babesia* sp., and *Anaplasma platys*. The latter pathogen was detected in a brown dog tick collected in Barangay 38A, Mangato East. This emerging infectious disease affects the platelets of dogs; humans are affected by other *Anaplasma* sp. that cause similar diseases.

***Rhipicephalus microplus*.** This tick is an ectoparasite of cattle and large ruminants throughout the tropics and subtropics. This is a one-host tick and it rarely feeds on humans or small mammals. *Rhipicephalus microplus* is a vector of pathogens, such as *Babesia bigemina* and *Anaplasma marginale*.

***Haematopinus tuberculatus*.** This louse feeds on large mammals, such as carabao and cattle. It is not known to feed on humans. One specimen collected in San Lorenzo tested positive for *Rickettsia felis*. However, the real-time PCR value was high, indicating a low number of *Rickettsia felis* pathogens in the sample. It is not surprising to find this pathogen in arthropods that are not traditionally considered vectors.

***Ctenocephalides felis*.** The cat flea is a cosmopolitan ectoparasite that feeds on a wide range of animals and will readily bite humans. For humans, the cat flea is a vector of *Rickettsia typhi* (the pathogen responsible for murine typhus), a filarial nematode called *Dipetalonema reconditum*, and *Rickettsia felis*. The last-named agent was detected in both flea specimens collected from dogs in Mangato East and San Lorenzo. *Rickettsia felis* is a pathogen that affects people around the world and causes a wide range of symptoms. Some of these symptoms are clinically difficult to differentiate from dengue. It is important to know that many *Rickettsia* are not spread by the bite of vectors but rather via the feces of fleas or lice coming in contact with mucus membranes or via inhalation. Therefore, humans do not need to be bitten by a flea to become infected.

In the disease prevention education portion of this visit, we reached approximately 1,000 people in 21 barangays throughout Laoag City and presented classes to the general public, public health personnel, nursing students, parents at a local school, city leaders, and to mothers whose infants were at risk of acquiring dengue in the following season (Figure 3). We also worked with the Philippine military and the city Department of Health in establishing and improving their medical entomology capabilities. Although no dengue vectors were collected (because we were sampling during the middle of the dry season), many other vectors were found, and we were successful in isolating pathogens from some of the ectoparasites. Thus, knowledge was gained about this area and our information was exchanged with Philippine public health personnel, as education is the key to disease prevention. Whether one is operating in the military or in the civilian sector, and regardless of the country, mosquito and vector surveillance is a critical component of any public health program. This is especially true when vector-borne disease is known to be in the area. Public health personnel must understand the goals of a surveillance program so that they can educate their leadership and the resident population. The basic goals of a vector surveillance program are to:

- Determine the species and abundance of vectors present.
- Monitor for introduced species and new competent vectors.
- Evaluate vector-borne disease risks.

- Determine the need for implementing management strategies.
- Determine the effectiveness of management efforts.

I sincerely appreciated the opportunity to serve the people of Laoag City, Philippines, on this mission. I would like to extend my gratitude to all the professionals with whom I served for their cooperation and support. Finally, I wish to thank USAPHCR-PAC for their expertise in identifying the specimens and pathogens collected on this survey. I certainly hope that our friendship and professional exchange of information will continue for years to come.

Figure 3. Mothers with children at risk for dengue.

Integrating Host Nation and Department of Defense Entomology Surveillance Efforts

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Abstract. Since 1950, there has been a continuous US military presence in the Republic of Korea (ROK) to assist in deterring aggressive military threats. US and ROK military forces have long shared military exercises and many Korean soldiers have served in US military units as Korean Augmentees To the US Army (KATUSA). Throughout this time, US preventive medicine personnel have conducted varying levels of arthropod and rodent surveillance to protect US and Korean military forces. Beginning in the late 1990s, the US military arthropod and rodent surveillance activities increased, and expanded collaborations were developed between US military forces and the Korean military and civilian public health communities (Korea National Institute of Health, Korea University, Seoul National University, and Konkuk University). The information derived through these collaborations has been equally shared and serves to protect US forces and the people in the ROK. Accomplishments include: temporal and spatial distributions and identification of rodent and arthropod pathogens and their vectors, relative prevalence of tick-borne pathogens, new distributions of spotted fever group rickettsiae, isolation of Hantaan virus from US soldiers that led to areas of transmission based on spatial differences in Hantaan virus, and a better understanding of the relative prevalence of scrub typhus. In addition, collaborative efforts with US counterparts (e.g., Walter Reed Biosystematics Unit, US Army Research Institute of Infectious Diseases, Navy Medical Research Center, Uniformed Services University, and the Armed Forces Pest Management Board) augmented DoD and Korea counterparts through the institution of new technologies. This led to the identification of new mosquito species and vectors of malaria, new species and distributions of ticks, and initial disease risk analysis modeling for malaria and Japanese encephalitis.

Presentation. During their occupation of the Korean peninsula prior to World War II (WWII), the Japanese logged the lush forested mountains and hillsides and exported the timber to Japan, leaving much of the country barren. WWII brought further devastation to the ecology of the Korean peninsula as a result of military activities (Figure 1). At the war's end, Korea was divided into North Korea (Democratic People's Republic of Korea, DPRK) and South Korea (Republic of Korea, ROK). This division was along the 38th parallel, and the heavily fortified demilitarized zone (DMZ, 248 km by 4 km) prevented the annual migrations of large herds of deer.

On June 26, 1950, North Korea initiated an invasion of South Korea, which resulted in a 3-year war ending in an armistice in June 1953 followed by periodic unprovoked skirmishes instigated by the DPRK. The Korean War resulted in the deaths of thousands of South Koreans, military and civilian, as well as supporting UN forces.

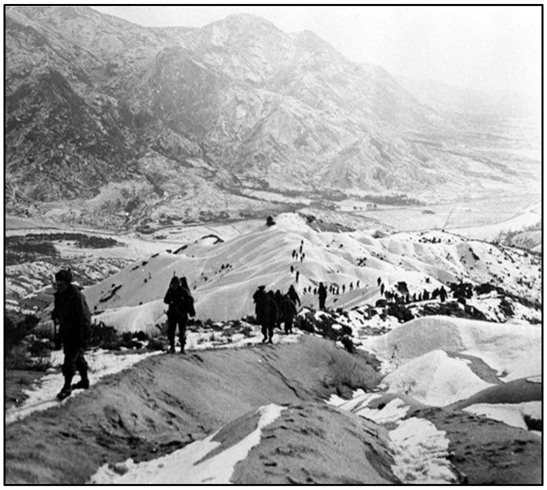

Figure 1. Denuded Korean mountains and hillsides resulting from logging operations during the Japanese occupation and military activities during WWII and the Korean War.

It also heavily impacted South Korea's economy and ecological landscape. Wild animal and bird populations declined as harborage and food were reduced through deforestation. Following the Korean War and with the aid of the US, South Korea's economy slowly evolved into a major industrialized nation with large population centers (Figure 2). In the late 1960's, a tree planting policy established by the Korean government led to the development of planted and volunteer forests that now cover the hillsides and mountains throughout South Korea (Figure 3), while much of the DPRK remains treeless.

Since 1953, the US military has maintained a military presence with "one-year-at-a time" deployments, which were not conducive to continuity and development of long-term preventive medicine goals. Until 1999 preventive medicine services were based on limited vector-borne disease surveillance, with the following basic assumptions: (1) malaria vectors and their distributions were defined; (2) Japanese encephalitis virus (JEV) was the only mosquito-borne arbovirus present in Korea; (3) scrub typhus, while present, did not present a real health threat to military personnel; (4) Hantaan virus (HTNV), a relatively severe disease with 5-10% mortality under even the best of medical care, and Seoul virus (SEOV), a relatively mild disease (<1% mortality), were the only two hantaviruses in Korea; and (5) flea- and tick-borne pathogens did not present a health threat to military personnel.

Figure 2. Seoul, a major city in South Korea, with a population exceeding 14 million.

Figure 3. Dairy farm near Dongducheon surrounded by forested hillsides and mountains.

Prior to 1992, preventive medicine assets included a robust 5th Preventive Medicine Unit (PMU) of approximately 150 personnel and unified peninsula-wide mission, although continuity and long-term vector-borne disease surveillance were very limited and resigned mostly to epidemiological investigations, e.g., the 1986 outbreak of 14 cases of HTNV among marines while training near the DMZ. In 1992, the 5th PMU was disbanded and replaced with three, 11-13 member medical detachments (MED DETs), preventive medicine (PM), and which provided "Area Support." This change of command direction was not conducive to a unified peninsula-wide PM program and also placed a burden on the MED DETs for administrative duties. The current force health structure in Korea consists of the 65th Medical Brigade (MED BDE), Eighth US Army, which is a Modified Table of Organization and Equipment (MTOE) Unit designed for a wartime mission and, as such, has limited resources and capabilities to conduct surveillance of arthropod- and rodent-borne diseases affecting soldiers, civilians, and family members deployed to the Korean peninsula. During the transition from the 18th Medical Command to the 65th MED BDE, the MED DETs (PM) were reduced from three to two (Figure 4). The MED DETs do not have the capability to assay rodent tissues for hantaviruses, a biosafety level laboratory (BSL)-4 agent, or arthropods for identification by polymerase chain reaction (PCR), or assay for vector-borne pathogens, including malaria, JE or other mosquito-borne viruses, tick-borne encephalitis, scrub typhus, murine typhus, leptospirosis, spotted fever group rickettsiae, Lyme disease, and other diseases yet to be described. To augment preventive medicine resources, the Chief, Force Health Protection and Preventive Medicine (FHP&PM), 65th MED BDE, with the assistance of the Regional Emerging Infectious Disease (REID) Consultant, collaborates and integrates host nation support, which includes the Ministry of National Defense (MND), Korea Center for Disease Control and Prevention (KCDC), and National Institute of Research (K-NIH), Seoul National University, Korea University, Konkuk University, Kosin University, and other government and non-government agencies which have the capacity to assay arthropods and rodents for known and unknown pathogens (Figure 4).

In addition, the 65th MED BDE relies on several US agencies to identify mosquitoes using DNA gene fragments by PCR, confirm vector identifications, analyze arthropods for currently known, unreported, and undescribed vector-borne pathogens, and model vector populations and diseases, e.g., malaria and Japanese encephalitis (JE). These agencies include the US Centers for Disease Control and Prevention (CDC), the Walter Reed Biosystematics Unit (WRBU), the Naval Medical Research Center (NMRC), the Armed Forces Pest Management Board (AFPMB), the US Army Public Health Command-Pacific (PHC-Pacific), the Uniformed Services University of the Health Sciences, the US Army Medical Research Institute of Infectious Diseases (USAMRIID), and the Armed Forces Research Institute of Medical Sciences (AFRIMS).

In 1999, an Entomology Consultant was added to the manning document of the 18th MEDCOM. The Entomology Consultant, through the Chief, Force Health Protection, provided oversight for a comprehensive national vector-borne disease surveillance program that addressed the recent introduction of malaria (1993) and other vector-borne disease issues. The Entomology Consultant provided valuable continuity by remaining in Korea from 1999-2006 on active duty and then as the REID Consultant (civilian contractor), 18th MEDCOM, after his retirement. In addition, a new Entomology Consultant was assigned for more than one year, which led to increased ability to address additional issues of vector bionomics and the distribution of mosquito, rodent, tick, mite, and flea-borne pathogens. Unfortunately, in 2008, when the 18th MEDCOM was replaced by the 65th Medical Brigade, the Entomology Consultant position was deleted from the manning document. However, the REID Consultant remained on as a civilian contractor, funded by the Armed Forces Health Surveillance Center (AFHSC), Global Emerging Infections Surveillance and Response System (GEIS) Operations Division, and continued to coordinate surveillance of vector-borne pathogens through the Chief, FHP&PM. Furthermore, as the MED DETs basic mission of vector-borne disease surveillance was limited, GEIS and the National Center for Medical Intelligence provided for unfunded laboratory support, which was then provided by Korean and other US agency collaborators.

The continuity for comprehensive vector-borne disease surveillance programs, provided by a long-term active duty assignment and as a civilian contractor spanning 11 years, resulted in many new findings that relate to the health and well-being of military personnel, civilians, and family members deployed or assigned to the Korean peninsula. A brief partial listing of accomplishments managed, coordinated, and conducted by the Entomology Consultant/REID Consultant, with the primary groups involved, includes the following:

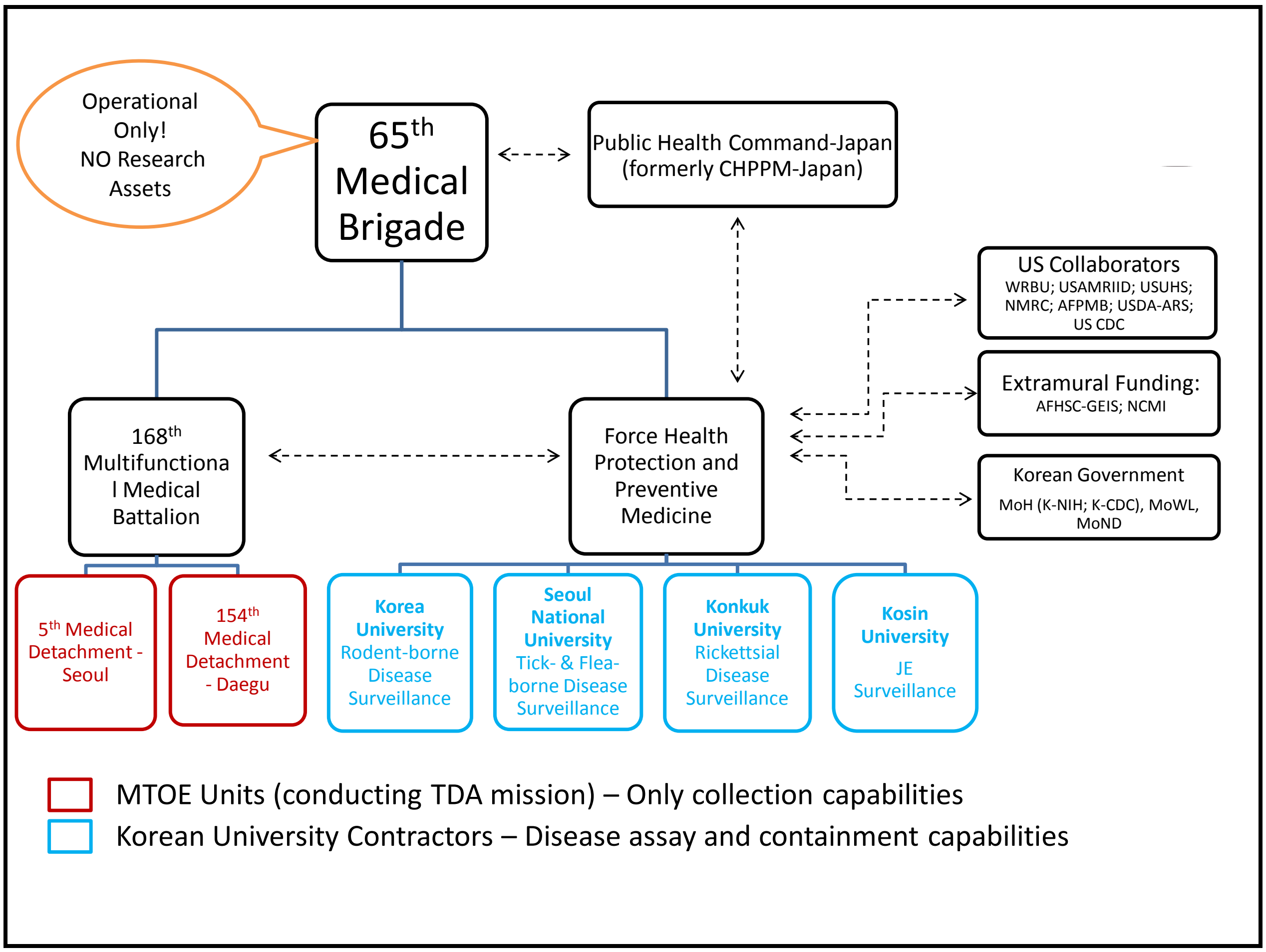

Figure 4. The 65th Medical Brigade structure and associated host nation counterparts.

FHP&PM Mosquito-Borne Disease Surveillance Program:

- Two new species of anophelines, *Anopheles kleini* and *Anopheles belenrae*, were described, (5th MED DET, WRBU);
- *Anopheles kleini* defined as the primary vector of vivax malaria in South Korea (5th MED DET, PHC-Pacific, WRBU, KNIH);
- Geographical distribution of *Anopheles* spp. defined, providing an improved assessment of malaria risks in the ROK (*An. kleini* accounts for >70% of all anophelines in the DMZ, about 30% of all anophelines 3 km from the DMZ, and <2% of all anophelines south of Seoul) (5th MED DET, WRBU, AFRIMS, KNIH);
- Epidemiology of vivax malaria in the ROK and US populations supported evidence that the greatest risk of malaria transmission was near the DMZ, where the highest populations of *An. kleini* were reported (5th MED DET, KNIH, KCDC);
- Preliminary evidence indicates vivax malaria risks are greater within the DMZ and in North Korea, as *An. kleini* accounted for >70% of all anophelines collected and had the highest sporozoite rates (38.9%) (5th MED DET, WRBU, KNIH);
- Vivax malaria risk models are being developed to define malaria risk based on the epidemiology of malaria among Korean populations and vector population abundance and distribution (WRBU);
- Epidemiology of US Forces Korea showed that replacing ill-kept insecticide-treated tents with air-conditioned barracks greatly reduced malaria transmission in a malaria high-risk area (Warrior Base) (5th MED DET, KNIH);
- Larval surveillance supported evidence that *An. sinensis sensu stricto* was the primary anopheline mosquito collected south of Seoul, while near the DMZ *An. kleini* was the most frequently collected through July (5th MED DET, WRBU, KNIH);
- Expanded the geographic and bionomic knowledge of *An. lindesayi japonicus* in the ROK (5th MED DET);
- Identified the presence of JEV in mosquitoes near the DMZ (5th MED DET, AFRIMS, USUHS);
- Identified the presence of Chaoyang virus (thought to be a mosquito virus) and an undescribed virus in the dengue/JEV serogroup of unknown epidemiology (unpublished data) (5th MED DET, PHC-Pacific, AFRIMS, USAMRIID, USUHS); and
- Developed preliminary models for JEV (USUHS, AFRIMS, 5th MED DET, Kosin University).

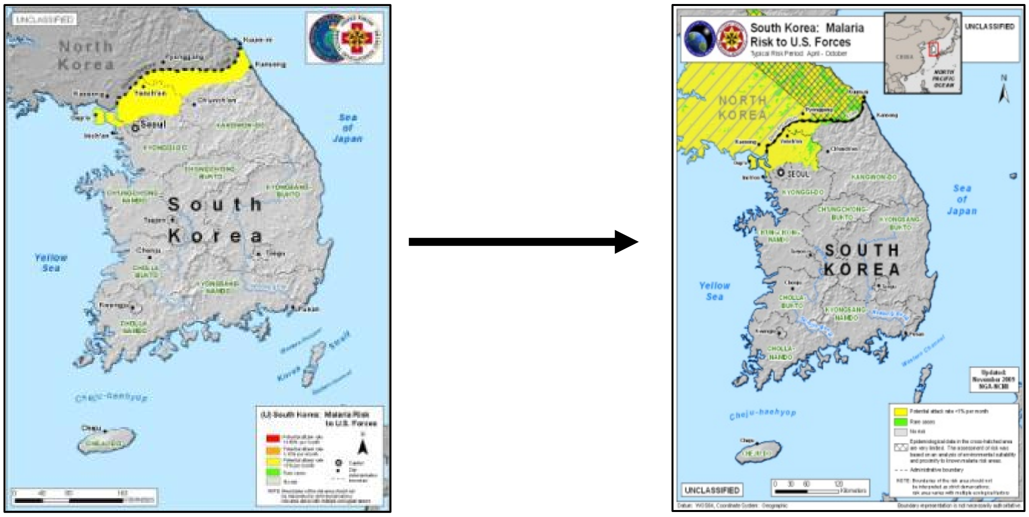

Figure 5. Malaria risk assessment provided by NCMI, based on information from malaria assessments among US and Korean populations, distributions of vector populations, and vector potential.

Primary Outcomes:

- Redefined the malaria high-risk map, which was developed and published by the National Center for Medical Intelligence (NCMI) (Figure 5);
- Data supported the development of vivax malaria risk assessment models (ongoing) (NCMI, WRBU, KNIH);
- Data supported the development of JEV risk assessment models (ongoing) based on the distribution of vector populations, swine farming, and JEV cases among Korean populations (KNIH, USUHS);
- Data supported the development of patient algorithms for encephalitis and meningitis cases reported at the 121st Hospital in Seoul to identify potential JEV cases; and
- Identified the potential for other arboviruses in Korea that serologically cross react with JEV, raising the need to isolate the virus in patient sera.

FHP&PM Rodent-Borne Disease Surveillance Program:

- Described two new rodent-borne hantaviruses, Soochong and Muju viruses (5th MED DET, Korea University);
- Described a new soricomorph (shrew)-borne hantavirus, Imjin virus (5th MED DET, Korea University);
- Identified HFRS seasonal risk patterns (late September-early December) that were correlated with high reproductive periods (August-September) and the infusion of young hantavirus-naïve populations during periods of movement to winter habitats (5th MED DET, K-CDC, Korea University);
- Defined geospatial variation among HTNV gene segments (Korea University);
- Identified the source of four HFRS infections based on epidemiological surveillance, which included identification and characterization of HTNV from patients and rodents in areas where the soldiers had previously trained (5th MED DET, Korea University);
- Showed that annual *Apodemus agrarius* populations and associated numbers of HFRS cases were similar, unlike annual cases of HFRS Puumala and Sin Nombre viruses that

increase/decrease with increasing/decreasing bank vole and white-footed mice populations, respectively (KNIH, Korea University);
- Identified the site of SEOV infection for an Airman cleaning a building at Yongsan Army Garrison, Seoul, and recommended proper methods for cleaning areas contaminated with rodent excreta to reduce risk of infection (5th MED DET, Korea University);
- Demonstrated relatively low risks for leptospirosis based on small mammal seroconversions (5th MED DET, Korea University);
- Demonstrated relatively low murine typhus (except for Twin Bridges Training Area) and relatively high scrub typhus seroconversions among small mammal populations (5th MED DET, Korea University).

Primary Outcomes:
- Provided epidemiological reports that identified HFRS high-risk training sites;
- Provided recommendations for reduced military training activities at HTNV high-risk training sites;
- Provided recommendations for cleaning rat-infested buildings where SEOV was acquired; and
- Provided risk assessments for arthropod-borne pathogens (scrub typhus, murine typhus) where small mammals are reservoirs and hosts.

FHP&PM Tick- and Flea-Borne Disease Surveillance Program:
- First report of *Rickettsia felis* in the ROK (in press) (5th MED DET, NMRC, Seoul National University);
- Identified murine typhus among fleas collected from small mammals (5th MED DET, NMRC, Seoul National University)
- Identified four new records of ticks, *Ixodes pomerantzevi* (small mammals), *Haemaphysalis ornithophila* and *Haemaphysalis phasiana* (bird ticks), and *Ixodes simplex* (bats) (5th MED DET, AFPMB, Seoul National University);
- First report of tick-borne encephalitis, Western subtype, from *Haemaphysalis longicornis* and *Haemaphysalis flava* collected in tick drags from Jeju Island (5th MED DET, Seoul National University);
- First report of *Rickettsia monacensis* from ticks collected from small mammals (5th MED DET, USAMRIID, Konkuk University);
- Preliminary investigation demonstrated the presence of at least one new species of *Rickettsia* parasites from ticks collected by tick drag (5th MED DET, USAMRIID, Konkuk University);

Primary Outcomes:
- Results led to an investigation of pre- and post-deployment sera from soldiers deployed to the ROK, which demonstrated a 0.2% and 2.0% seroconversion for scrub typhus and spotted fever group *Rickettsia*, respectively (NMRC); and
- Identified potential increased disease risks for military personnel (training exercises), civilians (work, training), and family members (recreational activities) for flea and tick-borne pathogens, e.g., tick-borne encephalitis, spotted fever group *Rickettsia*, murine typhus, and scrub typhus.

In summary, it is imperative that US Forces Korea have an understanding of described and yet to be described health threats on the Korean peninsula prior to the onset of hostilities or in the event of humanitarian efforts due to a natural disaster. Cooperative relationships with the KCDC, KNIH, MND, and various universities provide the needed interface with US Forces Korea to identify annual and seasonal disease trends that may degrade military operations and impact all categories of military and civilian personnel deployed or assigned to the ROK. Personnel continuity is essential for these programs to provide and develop the most benefit from long-term specific goals. Continued extramural funding, such as that provided by GEIS and NCMI, is necessary to meet the additional requirements for detection and analysis of emerging pathogens and to provide disease risk assessments. Such funding augments force health protection for US military personnel training at more than 100 sites near the DMZ, as well as US military, civilians, and dependents residing at US installations in Korea or engaging in recreational activities.

Navy Entomology: Implications for Vector-Borne Diseases in Central and South America, a Civilian Collaborator's Perspective

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Abstract. The United States (US) Department of Defense (DoD) is a leading funder of research on neglected tropical diseases, with a strong emphasis on vector-borne diseases. Since its inception in 1983, Naval Medical Research Unit Number Six (NAMRU-6; formerly the Naval Medical Research Center Detachment-Peru or NMRCD-Peru) has been a leader in operational research and surveillance of vector-borne infectious diseases that threaten local populations and military personnel in the region, including malaria, dengue fever, yellow fever, viral encephalitides, other arboviroses, rickettsioses, leishmaniasis, and Chagas' disease. The entomology program at NAMRU-6 serves as a regional platform for conducting research and assisting in surveillance throughout Latin America. NAMRU-6 enjoys productive relationships with ministries of health (MoH) and ministries of defense, as well as collaborations with the US Agency for International Development (USAID), the US Centers for Disease Control and Prevention (CDC), the US National Institutes of Health (NIH), the Pan American Health Organization (PAHO), and numerous US universities. Cross-disciplinary integrated studies of pathogen and vector are carried out between the NAMRU-6 Departments of Entomology, Virology, and Parasitology in the Amazon city of Iquitos, Peru, where NAMRU-6 has 90 permanent field and laboratory staff. Over 10 years of research have focused on the role of the mosquito *Aedes aegypti* in the transmission dynamics of dengue fever and novel intervention strategies to control this vector. Malaria work has investigated the biology, taxonomy, population dynamics, and distribution of the mosquito vectors of the parasite *Plasmodium*. Other research areas include insecticide resistance of important vector species (Peru and Ecuador), evaluation of new repellent formulations and personal protection devices, semiochemical attractants for sand flies (Colombia), and a mass-rearing facility for the mosquito *Anopheles albimanus* (Peru).

The objectives of this presentation are: (1) to provide an overview of the exciting and growing research program at Naval Medical Research Unit Six, and (2) to demonstrate that military research programs often collaborate closely with academic institutions, resulting in a stronger and better-funded research agenda than single institution projects.

The DoD is a committed and vital funder of research on neglected tropical diseases (NTD), often supporting and filling a major research void. Although the DoD's top priority is troop protection, there is increasing recognition that NTDs contribute to political instability, providing further justification for the US military's involvement in this area of research. Military research units provide a stable research infrastructure in terms of physical facilities and intellectual continuity, which enable long-term longitudinal studies and operational research. Further enhancing these types of studies are collaborations with universities and government agencies (Peruvian, US, and international). These types of collaborations facilitate leveraging of DoD money with non-DoD funding sources, such as the National Institutes of Health, National Science Foundation, Bill and Melinda Gates Foundation, and others. The military structure facilitates multidisciplinary studies between different departments, such as those among the NAMRU-6 Departments of Virology, Entomology, and Parasitology. Herein we provide examples of this research synergy from NAMRU-6's program in Peru.

Stable Research Infrastructure. NAMRU-6 is one of five infectious disease research laboratories worldwide Outside the Contiguous United States (OCONUS) and serves as the regional research platform throughout Latin America (Figure 1).

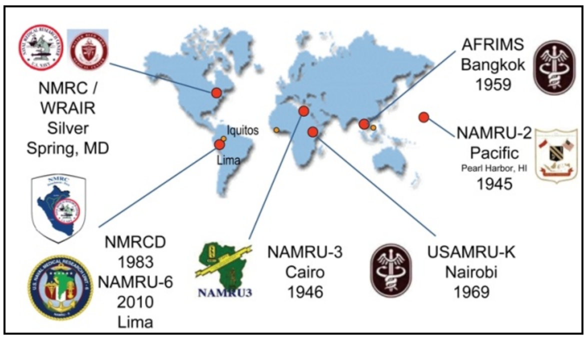

Figure 1. Locations and year of inauguration of the five DoD infectious disease research laboratories (red dots) OCONUS. Satellite laboratories (orange dots) are located in Iquitos, Peru, Phnom Penh, Cambodia, and northern Ghana.

NAMRU-6's primary facility is located in the capital city of Lima, Peru, situated in the southern coastal desert (Figure 2). In addition to the site in Lima, NAMRU-6 possesses a satellite laboratory in Iquitos, Peru, a city of approximately 380,000 people (INEI 2008) in the Amazon Basin (Figures 3 and 4).

The mission of NAMRU-6 is "to detect infectious disease threats of military or public health importance, develop mitigation strategies against those threats, and to test those strategies." This is accomplished through the following activities: (1) detecting emerging infectious disease threats through surveillance studies, most notably on febrile diseases and pandemic influenza; (2) increasing the capacity for host nations to conduct research and surveillance through training and technical transfer activities; (3) executing biomedical research on vaccines, medicines, diagnostic tests, and vector-control interventions; and (4) supporting the US diplomatic mission in Peru and Latin America. NAMRU-6 has 16 US military personnel, 321 full-time Peruvian staff, and between one and four civilian contract employees, and has an annual budget of about 15 million dollars primarily coming from research grants. The Lima facility possesses 37,000 square feet of laboratory space, including two Biosafety Level (BSL) 3 Laboratories, and one of the only Association for Assessment and Accreditation of Laboratory Animal Care International (AAALAC) certified animal facilities in South America, as well as an Iquitos-based 5,000 square foot BSL 2 facility that includes an insectary (Figure 3, inset). A list of NAMRU-6 current collaborators is shown in Table 1 and a comprehensive list of our ongoing projects is shown in Figure 4.

Figure 2. Naval Medical Research Unit 6 in Lima, Peru.

Figure 3. Naval Medical Research Unit 6 Iquitos Laboratory. Inset – Insectary facility.

Figure 4. Location and title of Naval Medical Research Unit 6 active research projects in Bacteriology, Emerging Infections, Entomology, Parasitology, and Virology.

Table 1. List of institutions currently collaborating with Naval Medical Research Unit-6.

Entity	**Organization**
Peruvian	Academia Armed Forces Ministry of Health Non-governmental Organizations (NGOs)
US Government	Centers for Disease Control and Prevention (CDC) National Institutes of Health (NIH) United States Agency for International Development (USAID)
US Department of Defense	Armed Forces Medical Intelligence Center (AFMIC) Biological Defense Research Directorate (BDRD) DoD Global Emerging Infections System (GEIS) Naval Medical Education and Training Command (NMETC) Naval Medical Research Center (NMRC) Southern Command (SOUTHCOM) Uniformed Services University of the Health Sciences (USUHS) US Army Medical Materiel and Development Agency (USAMMDA) US Army Medical Research Institute of Infectious Diseases (USAMRIID) Walter Reed Army Institute of Research (WRAIR)
International	Ministries of Health in 10 Nations Non-governmental Organizations (NGOs) Pan-American Health Organization (PAHO) World Health Organization (WHO)
US and European Universities	Liverpool School of Tropical Medicine and Hygiene London School of Tropical Medicine and Hygiene State University of New York, Stony Brook The Johns Hopkins University Tulane University University of California, Davis University of California, Los Angeles University of California, San Diego University of Texas, Medical Branch, Galveston University of Washington

Ongoing Entomology Projects. NAMRU-6 Entomology has ongoing projects in Peru, Ecuador, and Colombia, including the testing of semiochemical attractants and surveillance for phlebotomine sand flies as well as a long history of carrying out insect repellent evaluations. It has been a regional leader in providing training for insecticide resistance testing using the CDC bottle bioassay as well as the WHO cone tests for regional health departments through the Amazon Malaria Initiative and a military-to-military training program in Peru, Ecuador, and Colombia (Figure 5). NAMRU-6 Entomology has been integral in mapping the distribution and infectivity of malaria vectors in the Amazon Basin, and helped document the invasion of the vector mosquito *Anopheles darlingi* into the region in the 1990s, when there was resurgence of *Plasmodium falciparum* and a dramatic increase in malaria transmission rates (Figure 6). Ongoing efforts include colonizing the malaria vectors *An. darlingi* in Iquitos and *An. punctipennis* and *An. albimanus* in northwest Peru. A large outdoor cage with enclosed vegetation and oviposition sites was designed to be tall enough to allow horizon fixation, which facilitates swarming and successful copulation of captive *An. darlingi* (Figure 7a). Successful colonization would greatly facilitate ongoing infection experiments with the malaria parasite, *Plasmodium*.

Since 2004 and in collaboration with the University of California, San Diego, NAMRU-6 Entomology has conducted infectivity experiments by testing sera generated against a series of antigens that interfere with the parasite's development within the vector midgut (Bharti et al. 2006).

Figure 5. A. Insecticide resistance testing training sessions. B. for WHO. C. CDC bottle assay methods.

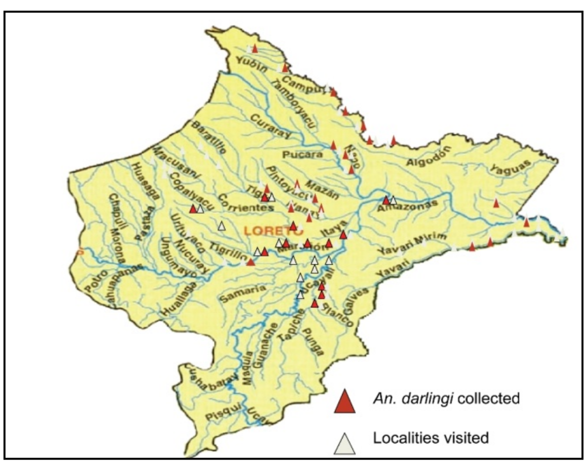

Figure 6. Distribution of *Anopheles darlingi* in the Department of Loreto, Peru.

At present, *An. darlingi* are collected using human landing collections, and transported to the Iquitos Field Laboratory, where they are provided a blood meal on chickens and allowed to oviposit. F1 progeny are raised to adults in the insectary and maintained on a sugar solution at ambient temperature. Volunteers with active malaria infections detected through a febrile surveillance study are recruited (Figure 7b, 9) and transported to the insectary, where they provide a blood sample from which infected red cells are obtained and mixed with test sera containing antibodies to putative transmission-blocking antigens. The blood/sera mixtures are placed in an artificial feeding system (Figure 7c) and groups of 25 mosquitoes are allowed to feed. After holding the mosquitoes for 7-9 days, the midguts are removed and viewed under a microscope (Figure 7d). The numbers of oocysts are counted for groups of mosquitoes that fed on either test or control (without blocking antibodies) mixtures; a reduction in the mean number of oocysts indicates possible candidates for a transmission-blocking vaccine. In the future, this approach may provide *Plasmodium*-infected mosquitoes to the Walter Reed Army Institute of Research (WRAIR) as a challenge to human volunteers receiving experimental malaria vaccines.

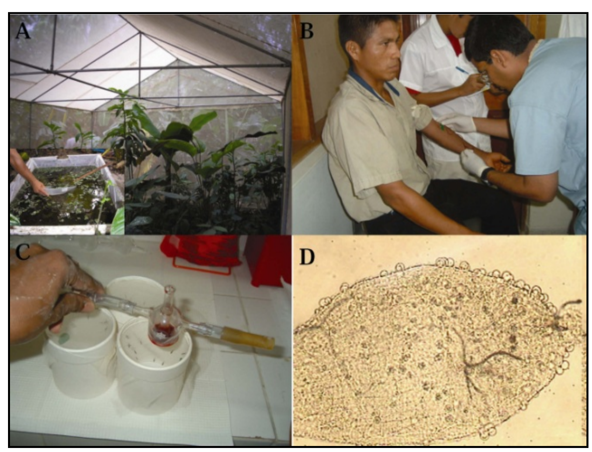

Figure 7. A. Colonization of *Anopheles darlingi* in an outdoor insectary. B. Experimental infection of mosquitoes with blood from active malaria patients. C. Using an artificial feeding apparatus. D. Oocyst development in the mosquito midgut.

The largest ongoing NAMRU-6 Entomology project is an experimental hut study, funded by the Bill and Melinda Gates Foundation in collaboration with the Uniformed Services University of the Health Sciences (Castro-Llanos et al. 2009). The objective of this project is to quantify contact irritant and spatial repellent behavioral activities based on chemical concentration and insecticide-treated material (ITM), utilizing compounds registered for adult mosquito control. Using mark-release-recapture methodologies, movement of mosquitoes into and out of the experimental huts can be monitored through window and door interception traps (Figure 8). A second component of the project employs outdoor traps to remove repelled and/or irritated host-seeking mosquitoes from the environment. Results from this research will be used to develop policy regarding house treatment methodologies and to implement a novel ITM push-pull system in dengue-endemic countries.

Regional Research Platform and Leveraging Opportunities. NAMRU-6's flagship research program is the regional febrile surveillance study, with surveillance sites in Peru, Ecuador, Bolivia, Honduras, and Paraguay (Forshey et al. 2010a). In collaboration with the ministries of health in these countries, febrile patients (>38°C with less than six days of duration) are recruited (Figure 9). First, a thick smear is evaluated to determine if the individual has a malaria infection (in Peru, this is part of a national program). If positive, these individuals are recruited into epidemiological studies looking at *Plasmodium* population genetics, including those identifying genotypes associated with drug resistance. Patients with malaria may have also been enrolled in a clinical trial collaboration with the Peruvian National Institute of Health comparing the efficacy of three different regimens of primaquine for the prevention of relapses of *Plasmodium vivax* malaria. In addition to malaria detection, febrile surveillance is used to identify individuals with respiratory infections who are tested for influenza and other respiratory viruses. For participants without a respiratory focus, an acute blood sample is assessed by viral isolation and IgM enzyme-linked immunosorbent assay (ELISA) targeting at least seven endemic arboviruses, including dengue virus, yellow fever virus, Venezuelan equine encephalitis virus (VEEV), Oropouche virus, Mayaro virus, and two Group C viruses. A convalescent sample is obtained 14-21 days later and tested for IgM-ELISA for evidence of seroconversion. This surveillance has been combined with studies testing new diagnostics and has identified active dengue cases that were recruited for detailed immunological studies looking at determinants of severe infection, such as cytokine activation and viral load. Finally, this surveillance has been critical in detecting disease outbreaks, including influenza (Forshey et al. 2010b), dengue (Forshey et al. 2009, Morrison et al. 2010), VEEV (Morrison et al. 2008), and rickettsiosis (Forshey et al. 2010c).

Figure 8. Experimental hut used to evaluate spatial repellency and contact irritancy of chemical insecticides and "Push-Pull" strategies for control of *Aedes aegypti*. Inset A: Marking mosquitoes for experiments. Inset B: Variation of coverage rates. Inset C: Recapture of mosquitoes with aspirators and in exit traps.

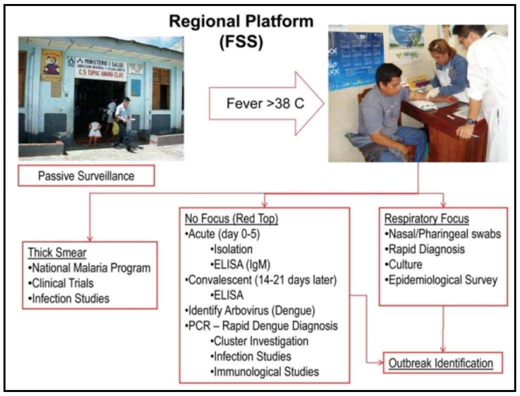

Figure 9. Flow diagram showing the types of research activities initiated through a regional febrile surveillance system.

Longitudinal Cohort Studies of Dengue Fever and *Aedes aegypti*. Since 1998, the NAMRU-6 Virology and Entomology Departments have collaborated with the University of California, Davis, Department of Entomology, on a series of longitudinal cohort studies with distinct objectives. The first, funded by the NIH from 1999 to 2003, had multiple objectives, including: 1) determination of the quantitative relationship between vector mosquito *Aedes aegypti* population densities and dengue virus transmission risk, 2) establishment of entomological transmission thresholds, 3) description of the spatial and temporal patterns of dengue virus and *Ae. aegypti*, and 4) identification of the most appropriate indices for measuring entomological risk (Getis et al. 2003; Schneider et al. 2004; Morrison et al. 2004a,b; Morrison et al. 2010). The second cohort collaboration, the Dengue Vector Control System (DVCS) evaluation study, carried out between April 2004 and October 2005, was designed to test an integrated entomological intervention developed at WRAIR (Morrison et al. 2005). A third cohort involving five city blocks located in 10 geographic zones (50 block total) was initiated in January 2006 to test the efficacy of targeted larval control, to assess the efficacy of the insect growth regulator pyriproxyfen, and to continue monitoring dengue incidence in preparation for potential dengue vaccine efficacy trials funded by the World Health Organization Tropical Disease Research Program (WHO/TDR), the Deployed War-Fighter Protection Program (DWFP), and the Military Infectious Disease Research Program (MIDRP), respectively. In November 2007 and 2009, a third and fourth cohort were recruited to study the role of human movement for dengue virus transmission dynamics and to test the efficacy of insecticide-treated curtains. For these five cohorts, the overall study design has varied with the research objectives, but each included geographically stratified sampling schemes, contiguous neighborhoods, and randomized cluster designs.

Each of these studies has monitored both dengue infections and levels of entomological risk simultaneously in the same homes and included a longitudinal component that monitored approximately 2,400 individuals over a 3-5 year period. Blood samples were collected from healthy cohort members at 6-9 month intervals and tested by plaque reduction neutralization tests (PRNT) for serotype-specific antibodies against dengue virus in order to detect seroconversion. All but one of these cohorts has included an active surveillance component to identify dengue cases, either through school- or community-based surveillance (Rocha et al. 2009). Febrile cases were identified during visits conducted 3-5 days a week. Acute and convalescent samples were obtained from these cases to determine if the cause of fever was dengue virus infection. These studies provided data on the clinical spectrum of dengue, the invasion dynamics of a novel serotype of dengue virus into an area, and the variation in the unapparent-to-apparent case ratio. Furthermore, active surveillance has identified dengue patients for more detailed immunological and epidemiological studies (e.g., cluster investigations). The procedures for community engagement and cohort recruitment (Figure 9), serological sampling (Figure 10), and entomological sampling using the pupal demographic survey and adult mosquito aspiration (Figure 11) have been standardized through 12 years of experience.

Figure 10. Community meeting held in Iquitos, Peru, for recruitment of longitudinal cohort participants.

Figure 11. Serological surveys carried out in Iquitos, Peru, for longitudinal cohort and active surveillance studies.

Leveraging of the 1998-2003 Cohort. A concrete example of how a DoD/university collaborative effort can build on a single cohort to achieve complementary research goals is illustrated by the 1998-2003 cohort study described above. This project was funded through two MIDRIP funding streams, one with the objective of measuring dengue incidence ($270,000 per year), and the other concerned with pathogenesis ($320,000 per year) along with a five-year NIH grant awarded to the University of California, Davis ($1,502,430 for 5 years). Each funding stream had unique research objectives, but all relied on the basic cohort design and it is unlikely that the individual projects would have been able to achieve their goals without having combined resources. During the course of this investigation, other research opportunities arose, including influenza surveillance and studies on VEEV epidemiology. This effort has led to four published articles on *Ae. aegypti* (Getis et al. 2003; Schneider et al. 2004; Morrison et al. 2004a,b), two on dengue epidemiology (Rocha et al. 2009, Morrison et al. 2010), and one article each on influenza (Forshey et al. 2010b) and VEEV (Aguilar et al. 2004). Furthermore, data generated during the course of the study were shared with the local MoH to aid in policy decisions. Most notably, during a serious outbreak of dengue virus serotype 3 at the end of 2002, cohort entomological survey data were used to assess the efficacy of emergency vector control measures. These surveys clearly demonstrated that the intervention had a significant impact on adult *Ae. aegypti* population densities (Figures 12 and 13) and further suggested dengue virus transmission rates were lowered. These data justified provision of additional funding in order to finish intervention and control measures in subsequent years.

Leveraging of 2006 Cohort. As described above, a total of 50 blocks, five each from 10 geographic zones, allowed for the simultaneous evaluation of five treatments. In other words, each of the 10 zones had five blocks receiving a distinct entomological intervention. Three funding streams, two with entomological outcomes and one with serological outcomes, allowed for leveraged support for this undertaking. A comprehensive experiment was designed that compared two targeted larval control strategies based on the analysis of *Ae. aegypti* productivity from different container types. The strategies, designed to reduce mosquito production by 58% and 92% respectively, targeted different combinations of containers for physical elimination or treatment with larvicide. The larvicide pyriproxyfen was used because of its superior safety profile. Targeted strategies were compared to the standard MoH strategy of controlling all potential *Ae. aegypti* larval habitats or 100% of containers found with standing water.

In order to compare the efficacy of pyriproxyfen to the larvicide temephos used by the MoH, two additional treatments were conducted. One treatment utilized interventions synchronized with the pyriproxyfen blocks (2 month intervals) and the second treatment synchronized interventions with the standard MoH schedule (3-4 mo intervals). Finally, on 20 of the blocks, longitudinal serological studies were also carried out to collect dengue incidence data for potential vaccine trials. The aim was to measure the impact of two vector interventions on dengue infection rates. Even though cohort studies are labor-intensive and expensive, particularly during establishment of infrastructure, the value added to each individual project is clearly dramatic.

A final example were the DWFP pyriproxyfen project experiments, which explored the ability of adult mosquitoes to transfer insecticides – in this case, pyriproxyfen – on their legs to additional aquatic habits (Devine et al. 2009).

To our knowledge, this was the first field demonstration of this phenomenon and has since been the subject of additional funding opportunities from both civilian and military organizations.

Figure 12. Standard pupal/demographic and adult *Aedes aegypti* surveys carried out in households in Iquitos, Peru, as part of longitudinal cohort studies.

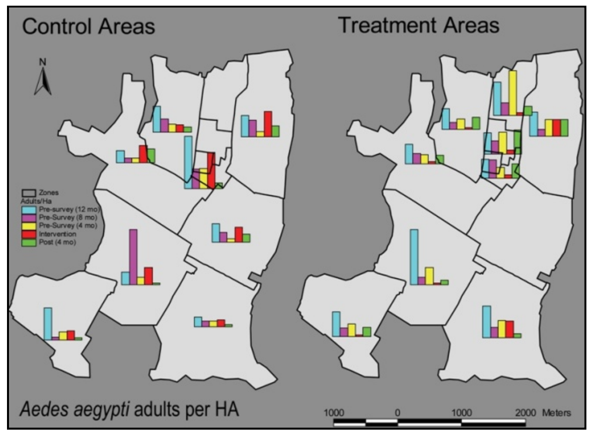

Figure 13. Comparison of adult *Aedes aegypti* per hectare (HA) collected in control areas (surveys were carried out within one month before emergency vector control measures were applied) and surveys in treatment areas (surveys were carried out within one month of the application of emergency control measures). Red bars = surveys carried out in November-December 2002 (just before or after control measures); Yellow bars = surveys carried out in the same houses four months earlier than the intervention period; Purple bars = surveys carried out eight months earlier than the intervention period; Blue bars = surveys carried out 12 months earlier than the intervention period; Green bars = surveys carried out four months after the intervention period.

Future Opportunities. In 2011, NAMRU-6 will be starting its sixth dengue cohort study, which will evaluate the efficacy of a novel attractant-baited lethal ovitrap to control dengue. In addition, dengue epidemiological studies will continue to focus on: 1) the role of human movement in transmission dynamics, 2) modeling disease spread, 3) factors influencing *Ae. aegypti* infection, and 4) the role of unapparent infections in transmission dynamics. Further dengue projects may include clinical trials of vaccines, chemotherapeutics, and rapid diagnostics. In addition to dengue, leishmaniasis and malaria will remain diseases of interest. The future remains bright for NAMRU-6 entomological studies, in Peru and beyond.

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Bringing COMFORT to Haiti: Operational Medicine Disaster Response During the 2010 Earthquake

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Abstract. In response to the January 12th earthquake in Haiti, the USNS COMFORT was deployed as part of Operation Unified Response-Haiti to provide medical support for one of the largest natural disasters in recorded history. Operation Unified Response-Haiti demonstrated the incredible logistical and organizational support that the U.S. Military can provide on short notice and that is critical during the acute phase of disaster response efforts. The operation also highlighted the inter-service and inter-agency cooperation that is required to successfully coordinate relief efforts with international, host nation and non-governmental organizations. Preventive medicine and disease control operations, particularly for malaria, were also critical in preparation for the Haitian relief efforts and increased in importance as the response moved into the endemic disease transmission seasons. Current updates on the status of relief efforts will be provided.